Isla Tac Power System

First Year Status Report: October 2000 through October 2001

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Introduction:

The IslaTac - Wind Diesel Rural Electrification Project was initiated under a cooperative agreement between the United States Department of Energy (DOE) and Chilean National Energy Commission (CNE) under the direction of the Chilean Rural Electrification Program (PER) to evaluate operational performance and social benefits of a prototype wind diesel power system in Chile's Region de Los Lagos. The system on Isla Tac has been implemented by five organizations; the Regional Government of the Region de Los Lagos, SAESA, the electric utility who holds operational responsibility for the power system, Wireless Energy Ltd., the system installer and organization currently providing maintenance to the system, the Comision Nacional de Energia (CNE) and the National Renewable Energy Laboratory of the United States (NREL). All of these organizations make up the project team who are currently monitoring the operation of the power system. The diversity of this group allows for an expanded of the system and what can be learned from the implementation of this project.

The system is designed to provide near grid quality electrical service on a continual basis. There is the implied understanding that this is a rural electric service and thus periods of no service will have to be tolerated for equipment failure or maintenance.

The electrical service for Isla Tac has been contracted directly between the local electric utility, SAESA and the Municipality for a duration of ten years with options for contract negotiation and renewal. A formal tariff agreement was negotiated and formalized by the CNE and SAESA which defines the quality of electrical service, electrical tariff structure and operational responsibilities.

The system was installed during the months of May through September of 2000 and commissioned and inaugurated in late October of that year. The system on the island of Tac was designed and installed as a pilot system, basically to demonstrate and gain experience with the use of wind energy technology for rural electrification in Southern Chile. With this in mind, the system is in part a learning experience for all of the people and organizations involved in the development of the project. The methodology of using a demonstration project prior to the implementation of a larger project has been shown effective in many areas and results in a better success rate for the following projects than if no pilot system is used. Because of this it is assumed that a number of installation and operational issues will be uncovered in the first year of operation, these issues will be addressed as they arise, with the understanding that any lessons learned will not be repeated in the implementation of any larger project.

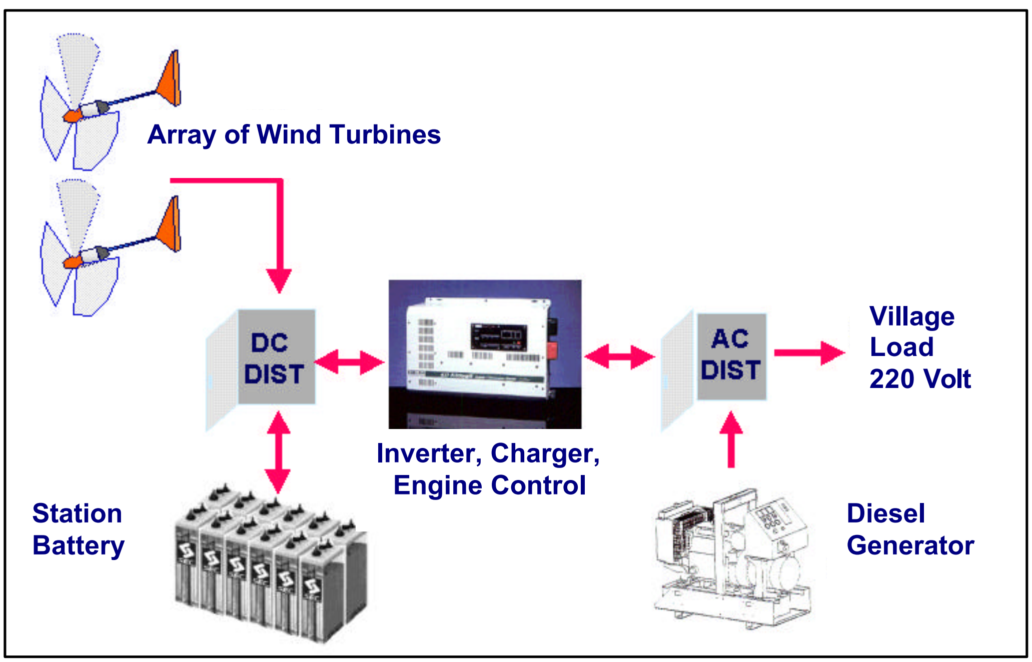
Power System Description:

The power system installed on the island of Isla Tac is designed as a DC based wind/diesel system with battery storage. The system is installed on a low hill in close proximity to the islands main community. A medium voltage distribution line provides the local backbone with low, 240 VAC, distribution to individual homes. In total 82 loads are connected to the localized grid including the school and community center.

The system is comprised of two Bergey Windpower Excel-R wind turbines rated at 7.5 kW each, a 17.5 kVA diesel generator, two parallel strings of SEC 6-M100-17 batteries in a 48VDC configuration with a nominal storage capacity of 100.6 kWh, and two stacked Trace Engineering SW4548E inverters with a control unit. Also included is an AC and DC distribution enclosures produced by Wireless Energy Ltd of Chile. The system is designed to provide a maximum power output of 13.8 kVA. The exact technical specification is included in the Appendix at the end of this report.

The system architecture and control typology of the Tac hybrid system is extremely simple and straightforward. An onboard PLC controller within the inverter system monitors and manages all aspects of power flow, fault conditions, battery charging and diesel engine control. The wind turbine controllers individually monitor the battery's voltage and provide charge when sufficient wind energy is available. Upon reaching low battery state of charge the inverter activates the diesel generator to initiate a complete battery charge cycle. The PLC control also is programmed to utilize the diesel generator for peak load management.

Block Diagram : Isla Tac Wind Diesel Hybrid Power System



Commissioning of the power system:

The Tac hybrid system was installed utilizing Wireless technicians, local contractors and community members. Due to limited large boat access to the island all materials had to be transported on small boats and then transferred to bull or tractor drawn sleds to reach the installation site.

Upon completing the installation, the hybrid system was put into trial operation for one week with artificial heating loads and monitored. The local technician was trained at this time on systems operations, maintenance, fault detection and recovery. Upon connection to the distribution grid, another week of tests were performed before connecting the complete community load.

Data Acquisition System:

A Data Acquisition System (DAS) provided by NREL was installed to monitor the performance of the power system as well as individual components. The system measures current from the two wind turbines, current into and out of each string of the battery bank and current through each of the power converters. The DAS also measures and records system active and reactive power, AC voltage, DC voltage, diesel generator operation and two wind speeds. The monitoring system is also equipped with a cell phone to allow remote data access and system monitoring. Not all parameters on the DAS have been operational due to damaged sensors and logger coding problems.

The DAS operates off energy created by the power system and is also subjected to measurement signals that may become out of bounds over the assessment period or due to sensor failure. In addition, if certain parameters are outside of a specified range, all of the data for that hour is considered suspect and can not be used for the analysis. Because of this, even though data is collected and reported for the whole month, the values only represent the actual collected data and not necessarily the total power generation because a certain number of points are not being recorded. A detailed description of system operation parameters from the installed DAS through the end of the first year of operation, ending October 2001 is provided in the Appendix.

Results: System operation through October 2001:

The table below summarizes the base model simulations originally used for Tac and *actual* data collected during the first year. In general, the system has complied with pre-defined operating targets even though operating conditions (grid losses, power factor) were less than optimal. It is interesting to compare the Tac system`s operating performance to original computer model simulations in hopes of increasing our understanding and accuracy of hybrid project designs

Yr. Operation	Generation KWh/day	Generacion KVA/day	Generation KWh/yr	Diesel Fuel Liters	Diesel Operation Hours	Maximum Demand KW	End Users
YR1	47	55.3	17000	3128	818	7.5	59
YR10	85	100	31000	9505	2394	15	78
YR1 Actual	54	89.4	19710	5300	2820	7.4	82

In general the Tac system has operated well, but due to distribution losses and low power factor conditions, the customers have received less power and the hybrid system has burned more fuel and engine hours than originally simulated. Total fuel consumption from October 2000 through October 2001 is approximately 5300 liters based on fuel delivery information from the power system logbook. Based on the estimated fuel consumption of 5300 liters, this results in a specific fuel consumption of **0.27 liters/kWh**. With this figure now calculated we expect to improve the specific fuel consumption performance by reducing losses in the distribution grid in the near term. A summary of monthly system performance is included in the Appendix.

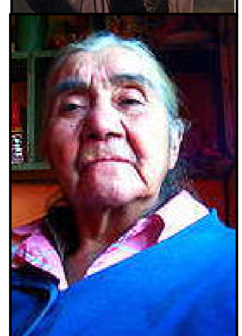
Wind Estimate:

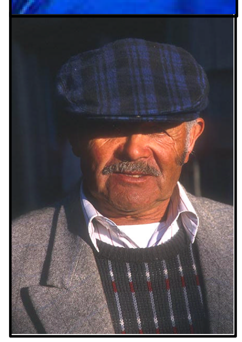
Wind data was collected on Isla Tac for two years prior to project implementation. An annual average wind speed of 5.4 m/s was recorded at a low point of the island. However, due to met tower shaddowing effects in winter months, NREL readjusted the anual average wind speed to 6 m/s on the island. An NREL wind map has been constructed for the Gulf of Ancud which supports a 6m/s scenario. Since implementation of Isla Tac, the wind speeds have been recorded in the data acquisition system. The data summary indicates a lower estimation than 6 m/s, however, we believe this is due to the lower relative position of the anemometer with respect to actual turbine hub height (24m).

Community impression of electrical supply and plant operation:

The Rural Electrification Unit of the Region de Los Lagos has visited Isla Tac several times to interview community members about the electrical service and system operation.

- In general the community is quite pleased to have electricity 24 hours per day and believe the wind-diesel generation system to be a reliable power source.





- With respect the electrical distribution system, the customers are conscious of the limited peak power capabilities of the system due to the current limiting grid design. The community has organized to limit peak loading conditions during critical hours buy manually displacing non-critical loads such as freezers to operate at off peak hours.

- The community is aware that the low power factor loads, such as fluorescent lighting, refrigerators, washing machines, pumps, have a negative effect on the system. Likewise, when SAESA installed power factor compensation in the island, energy consumption increased immediately.

- Many individuals have commented that they believe that the fixed fee tariff is considered expensive for some individuals who have very low monthly energy consumption. For example, one user who is using 20 kWh every two months pays $13,000 pesos which results in a per kWh cost of $650 pesos. Another user, with a larger usage of 293 kWh every two months pays $62,000 pesos, receives a lower cost of 211 pesos/ kWh because the monthly fee is spread over a larger energy usage. Clearly some measures need to be made for low consumption users that still reflects the per house expenses experienced by the utility.

- The cost of electrical energy for domestic use has dropped by 75-90% with the arrival of the wind diesel electric system. Studies conducted on the island before the arrival of electricity indicate that end users we paying approximately $2500 pesos per kWh for small batteries, candles, small engine generators and kerosene lanterns. Further, the system now provides 24 hour power and electricity for the clinic and school.

- The system was designed for residential applications and suffers from demand limitations. The community would like to consider utilizing the same system for more productive use applications and this may be limited by system size.

Load Evaluation:

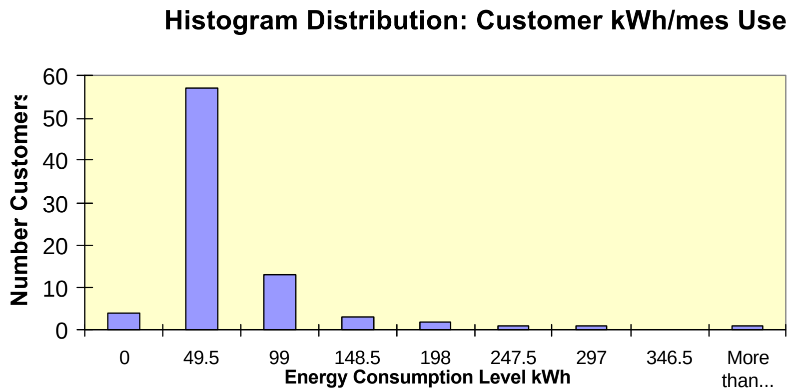
A lot of data has been collected on the energy consumption and community requirements during this pilot project. The most interesting information has been found in the community's ability to adjust their consumption habits to suit the generation capabilities of the power system.

The islanders have invested heavily in domestic equipment to dramatically improve their quality of life standards on the island. The following chart summarizes the current distribution of domestic equipment within the community. It is interesting to note the high number of electrical irons still being used despite their being banned initially. It seems the cultural interest to have pressed clothing is very strong.

Radios	70	Battery Chargers	15
Television	85	Electric Drills	12
Computer	1	Electric Saws	4
Washing Machine	40	Clothing Spinner (Dryer)	16
Refrigerator	18	Freezer	3
Electric Iron	30		

The following histogram distribution of energy consumption per customer has been created with *three* months of billing information for 82 customers. Although the majority of clients consume 49 kwh per month, it is apparent that some productive activities exist in the form of small markets, fish freezers, with much higher consumption. Further analysis is required to explore future productive use potential in the island.

kWh/Mes	*Customers*
0	4
49.5	57
99	13
148.5	3
198	2
247.5	1
297	1
346.5	0
More than...	1
Total	82



Monthly generation versus consumption:

In monitoring the wind diesel system's monthly energy production with the NREL data acquisition system and tracking monthly billable kilowatt hours per household, we are able to evaluate potential system losses, phantom loads, and faulty meter readings. In general, an energy loss of approximately 20% between the generation plant and the customer meters has been registered in the first months of 2001. We believe that as of July of this year, the load data has not been very reliable.

Wireless and SAESA are studying a variety of factors that may or may not be contributing to the losses in hopes of optimizing the Tac distribution network in the near term. A few issues being considered include:

1. Grid losses.
2. Faulty meters.

3. Improperly operating power factor compensation equipment.
4. Data collection errors on data acquisition system.
5. Multiplying effect of low power factor on network losses and inverter performance.
6. Newly introduced phantom loads.

Operational Problems:

There have been a number of problems that have been identified over the last year of system operation. These items have been identified by one or more of the project partners and deals primarily with the way that the system is operated or forced to operate. As with the problems identified during the commissioning process, this is the primary reason that pilot projects are implemented prior to the implementation of a larger electrification project.

1. Mismatch in regulation voltage of the wind turbine and the high voltage cut out setting from the inverter. There have been several recorded instances in which the inverter has shut down due to high battery bank voltage.

    Analysis: It was determined that the inverter high voltage shut off was not high enough for periodic battery voltage peaks caused by the wind turbine. For this reason during times of high renewable power, the turbines would charge the battery above the disconnect voltage of the inverter – causing inverter shutdown

    Solution: The inverter high voltage disconnect setting must be set much higher than the regulation voltage of wind turbine voltage control systems.

    Current Status: The inverter high voltage disconnect was adjusted upward to above the high regulation voltage of wind turbine voltage control systems.

2. Unusually low power factor seen on the power system.

    Analysis: An unusually low power factor has been observed on the power system, in the range of 0.6 to 0.8, independently by SAESA and Wireless Energy data acquisition. It was determined that this was likely due to the use of low efficiency fluorescent lighting installed in the homes as part of the interior installations. Because the inverters do not register power factor, they are unable to account for the additional load when undertaking system control functions. The physical ramification of this is that during times of diesel operation the inverters were overloading the diesel and causing the diesel circuit breaker to throw, thus causing system shutdown once the batteries had been depleted. To alleviate this problem, the charge setting for the diesel had to be reduced dramatically, essentially reducing the unit capacity by almost 40% so that the inverter would not overload the circuit breaker. Because of this the diesel has not been able to charge the battery during periods of high loading as was originally designed. This problem has resulted in more diesel operation than predicted in system design.

    Solution: Discussions were held between SAESA, Wireless Energy, the Regional representative to CNE and NREL to determine likely scenarios and possible solutions. SAESA agreed to install capacitor based phase shift devices on the power system to eliminate some of the loading due to reactive power. In the future high efficiency ballasts should be installed.

    Current Status: Implemented in July 2001. Currently under evaluation.

3. Low load operation of the diesel generator.

    Analysis: Observations of plant operating have indicated that the diesel is running unloaded or at light loads for periods that may last up to six hours. One cause may be due to pronged float charge that is incorporated into the inverter charging algorithm, which forces the diesel to provide a very small current to finish charge the battery. Because of this low load operation the

diesel is not kept at a proper operating temperature which allowed unburned fuel to seep into the oil pan. This resulted in a higher level of system maintenance and increased engine ware.
Solution: Place controls to reduce engine run time at light loading including reducing the battery float charge parameter in the inverter control menu.
Current Status: The duration of the battery float charge, controlled by the inverter, was reduced to 20 minutes from two hours. Under further analysis to optimize SFC/COE performance.

4. Shorts on the grid shutting down the inverter
   Analysis: The circuit breakers used in the step down transformers along the distribution network act slower than the inverter short circuit sensing. When there is a short on the low voltage grid, either caused by natural or unintended reasons, the inverter senses the short circuit and shuts down before the circuit break at the step down transformers have time to throw. Thus the whole island power system is brought down instead of just one section of low voltage line.
   Solution: Place fast acting fuses or circuit breakers at each of the local transformers that will function before the inverter so that the power for the whole community is not lost due to one short.
   Current Status: Under further analysis.
5. Energy efficiency training on the island and implementation of energy efficient lighting.
   Analysis: Initial training sessions were conducted as part of the program implementation. Although this did include general electricity safety and a review of the tariff, it did not cover energy efficiency and utilization issues to the extent necessary. Training on the use of electric service, the true costs of not using energy efficient appliances and providing guidance on proper component purchase needs to be completed. In addition, more permanent energy efficiency and safety displays need to be created or obtained and posted at popular locations within the community for those unable to come to training sessions. Such places could include the school and community center.
   Solution: Discussions undertaken between NREL, CNE and the regional government representative.
   Current Status: Under planning.

Maintenance of generation system and distribution network:

Wireless Energy is under contract by SAESA to maintain both the generation and distribution systems in addition to local billing administration and fuel delivery. A local technician was formally trained by Wireless and SAESA in all technical, safety and administrative functions. The technician communicates with Wireless periodically to coordinate service support requirements and adjust system operating parameters if necessary.

Items for future discussions:

A number of issues have been identified by one or more of the pilot partners that have been identified for further consideration, either for this project, or any future remote power system implementations. This list is not considered complete and does not imply that any action will be implemented now or in the future.

Extra / deferrable productive loads:

It is clear that at times the power system is unable to use all of the energy available from the wind turbines. Discussions on the use of this extra power have been undertaken between Wireless Energy, the Representative from the Regional government, and NREL. Items that are proposed include water pumping, in place of the diesel pump currently used to maintenance the islands water supply, ice making and a communal refrigeration system. More discussions on this topic will be required before any specific action is undertaken.

Tariff Structure:

In an ideal village power system, a proper tariff structure would be utilized such that incremental production capacity could be added to meet rising energy demand. The Isla Tac projects requires further definition of the future energy production levels, particularly with respect to productive use.

Costs information:

As a pilot project for the remainder of the islands in the Gulf of Ancud, it is important to understand the cost associated with the installation, operation and maintenance of these systems so that accurate assessments can be made to the costs of these power system in comparison to other alternatives. Discussions are underway with Wireless Energy to provide information on the cost of system implementation, operation and maintenance

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Nelson Stevens is founder and Director of Wireless Energy Chile Ltda, located in Puerto Montt, Chile. In 1996, Wireless Energy initiated operations with the sole vision of local manufacture and service of renewable energy technologies for industrial and rural development applications in the Southern Cone Marketplace. Within the industrial sector, Wireless Energy is the leading provider with over 1200 installations of high reliability solar, wind and hybrid solutions for rural telecommunications, mining and military applications. In the rural development sector, Wireless has implemented a series of solar and wind powered water pumping systems for large scale irrigation and animal use. Wireless works with small and moderate scale solar, wind and micro-hydro power generation for remote communities and small scale productive use activities. ***www.wireless-energy.com***

Appendix:

1. Equipment Specification:

The following section provides a detailed description of the equipment used in the power system. This information is supplied to provide a transparent system design and specification.

Wireless Energy Tac Hybrid Power System E15-D17.5-B98-V48-I9:

Diesel Engine:
Lister Peter 17.5 KVA, 14 kW, 220VAC three phase 1500 RPM Serial number EAAL006791.
F.G. Wilson Ltd Larne BT4-1EJ U.K.
Fuel Tank specification:
1000 L tank, Certified, Blue
Battery Specification:
Battery Bank 98 kwh (24hr.), 48 Volt, Deep Cycle Lead Acid, Traction, 6-M100-17 batteries.
Two strings of 24 cells 1024AH @ 24 hour rate, 1.8 vpc
Wind Turbines
2 x Bergey Windpower Co. VCS-10's with 48 V DC output.
2 x Bergey Windpower Co. Excel-R, 110 Volt winding
2 x Wireless Energy 24m, three stage guyed lattice towers
2 x Transformers. 30 KVA, 480/240, 36 amps primary. Catalog number WS363
Power Electronics and switching:
2 x Trace Engineering SW4548E with stacked parallel interface
Trace Engineering AC Disconnect / Conversion Module –
Wireless Energy: TD AC – AC Junction box with diesel connection switch.
Wireless Energy: TD CC – DC Junction box with fuses for wind turbines and inverters

Data Acquisition System (provided by NREL):
A Data Acquisition System (DAS) designed to monitor a wind based stand alone power system incorporating two wind turbines, a diesel engine and battery bank. Contained in a 36"x30"x8" gray fiberglass enclosure. The system contains six (6) Ohio Semitronics signal conditioners and sensors to measure current from two wind turbines, current into each string of the battery bank and current into each of the power converters. The DAS also measures and records system power, AC voltage, DC voltage, diesel generator operation and two wind speeds. The monitoring system is also equipped with a Motorola Cell phone, electronic serial number SUN 1905EC H9, a Campbell Scientific CR10 data logger, Serial number 8997, cellular modem, serial number 3770 and a signal multiplezer.

2. Summary of Data Acquisition System (DAS) 2001

See Attached.