Case Study: Las Gallinas Valley Sanitary District Reclamation Pump Station Solar Pholovoltaic Project

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ABSTRACT

In early 2004, Las Gallinas Valley Sanitary District, which serves residents of Northern Marin District, completed the installation of an 81-kilowatt solar photovoltaic (PV) power system that provides electricity for its reclamation pump station.

After completing a competitive proposal process, the District contracted with EI Solutions (formerly Prevalent Power, Inc.), a solar power systems integrator, to engineer, finance and install the PV system. The system was designed to zero the building's electricity bills and eliminate harmful emissions, initially saving the District around $22,000 per year.

The system purchase was financed in part with funds from California's rebate program; construction financing was provided by EI Solutions and its suppliers. Over its lifetime the system will generate $900,000 in direct energy cost savings. The system is expected to pay for itself in about 11 years, and will then provide another 20 years or so of "free" power to the District.

This case study provides an inside look at the PV engineering process, presents a set of best practices in PV system design and installation, and examines the economic and environmental rationale for purchasing the system.

ABOUT LAS GALLINAS VALLEY SANITARY DISTRICT

Las Gallinas Valley Sanitary District (LGVSD) provides sewer services to over 32,000 residents of Marin County in an area that extends from the Marin Civic Center to Marinwood. On average, the District treats 3.56 million gallons of wastewater per day. During winter months, treated effluent is discharged to Miller Creek, eventually making its way to San Pablo Bay. During the summer, the effluent is used to irrigate District pastures. Some evaporates, and some is stored in the District's ponds. The rest is treated to tertiary standards and supplied through a partnership with Marin Municipal Water District to local users for landscape irrigation, cooling tower water, county jail use, and car washes. LGVSD has taken a leadership role in its service area providing information to local residents, businesses and schoolchildren about wastewater treatment, pollution prevention, recycling and the environment. The District is operated by a Board of Directors elected by the voters within the District's service area.

ENERGY USAGE & COST ASSESSMENT

The District hired consulting engineer Tim Holmes of Kenwood Energy to develop a plan to increase the pump station's overall efficiency and power the station with solar power. The planned pump station upgrades significantly reduced the total energy required to pump reclaimed water to and from the District's ponds and to the pasture irrigation pivots. The solar power system was sized to meet the reduced pump station energy load and zero the pump station's energy bills. Mr. Holmes also helped the District to select and manage a system integrator to supply and install the system. After completing a competitive selection process, the District selected EI Solutions (formerly Prevalent Power) to engineer, design and install the system.

PV SYSTEM SIZING & ELECTRICAL ENGINEERING

PV system sizing is an iterative design process that seeks to maximize electrical generation and utility cost savings by:

- Fitting the PV system's seasonal output to the building's energy usage pattern
- Evaluating the impact of a building's net energy usage on the overall cost of energy under different rate scenarios, and
- Developing an electrical and structural design suited to the building and specified equipment.

The process of sizing the solar power system generally focuses on four major variables: the amount of sunlight available (insolation), the seasonal variation in insolation, the target energy to be generated and the performance characteristics of the PV components. California requires utilities to provide net metering to solar power generators. Under net-metering rules, customers can export energy to the grid when they're generating in excess of their load. Without net metering, a solar power system's peak summertime output could not exceed daily summer usage. And, if energy usage is inconsistent or periodic, a customer would lose excess energy to the grid. Net metering solves all of these problems and allows the engineering team to focus on annual energy usage.

Rough System Sizing

For LGVSD, the engineering team initially focused on sizing the system to completely replace the pump station's usage of 308,000 kWh per year. However, the District's engineering team determined that planned energy efficiency upgrades and modified operating schedule would reduce usage by approximately 45% to 169,000 kWh/year. The team then used 30 years of local insolation data to determine the solar resource on site for the planned orientation of the array. That data indicated that the site receives an average of 1,964 full sun-hours of insolation per year.

A sun-hour is defined as one hour's worth of full-intensity sun—which is defined as 1000 Watts per square meter at the Earth's surface. The reality is that at the start and end of the day, the available sun is much less than this. And often at solar noon, the insolation is a little higher than this. The annual insolation measurement is the sum total of sun energy available on site.

To establish a starting point, the team divided the 169,000 kWh by 1,964 sun-hours to get a rough solar power system size of 86 kilowatts (peak AC power output). This represents the maximum target power of the system at the point of interconnection with the utility.

Savings Strategy & Rate Selection

The engineering team determined that the best savings opportunity was to undersize the system and switch the pump station to PG&E's A-6 time-of-use (TOU) metering schedule. A-6 is a non-demand-metered seasonal TOU schedule. That means the customer's bill is based on energy usage only and does not have a demand component. Energy under A-6 is priced in three tiers: off-peak (nighttime), partial peak during morning and evening, and peak from noon to 6PM during the summer. Peak rates range from \$0.3464 per kWh during summer to \$0.1711 in winter. By combining the A-6 rate with net metering, the system can take advantage of differential pricing to favor the customer.

By sizing the system to export energy during the summer, the District is able to "sell high" and build up a credit that can then be drawn down during the winter when rates are lower. The resulting price leverage actually enables the District to bring its annual net utility bills to zero while only generating about 80% of its actual energy needs. Figure 1 below demonstrates this dynamic. The conclusion from this exercise indicated an appropriate system sizing of 70 kW (AC peak power).

System Size Refinement

To refine this sizing, the team next had to determine what solar module and inverter would be used in the system. Based on factors such as price, performance, and availability, the team chose BP Solar's BP 3160 (160 Wstc) module.

The team also determined early on to use the Xantrex PV series grid-tie inverter. This is largely because Xantrex's PV series is the dominant inverter manufacturer for systems of this size. The inverter has a peak efficiency of 96% converting DC power to AC power.

To get the needed DC array power (before conversion to AC), the AC power rating is divided by the inverter efficiency.

$$70.0 \text{ (AC)} \div 96\% = 72.9 \text{ kW (DC)}$$

The modules are rated at 160-Watts peak power under standard test conditions (STC). However, the team uses the PV USA test conditions (PTC) rating of 142.1-Watts per module. The inverter requires an input voltage between 300 and 600 volts DC power. To hit that input gate, the modules are wired in 12-module series circuits. That means the actual array has to be a 12-module multiple of the PTC rating. The final system size was determined to be a 504-module array with a rating of 71.6 kW(DC).

SYSTEM MECHANICAL & ELECTRICAL DESIGN

Following system sizing, the team completed the design phase by adapting the system's mechanical design to the site. The major engineer-

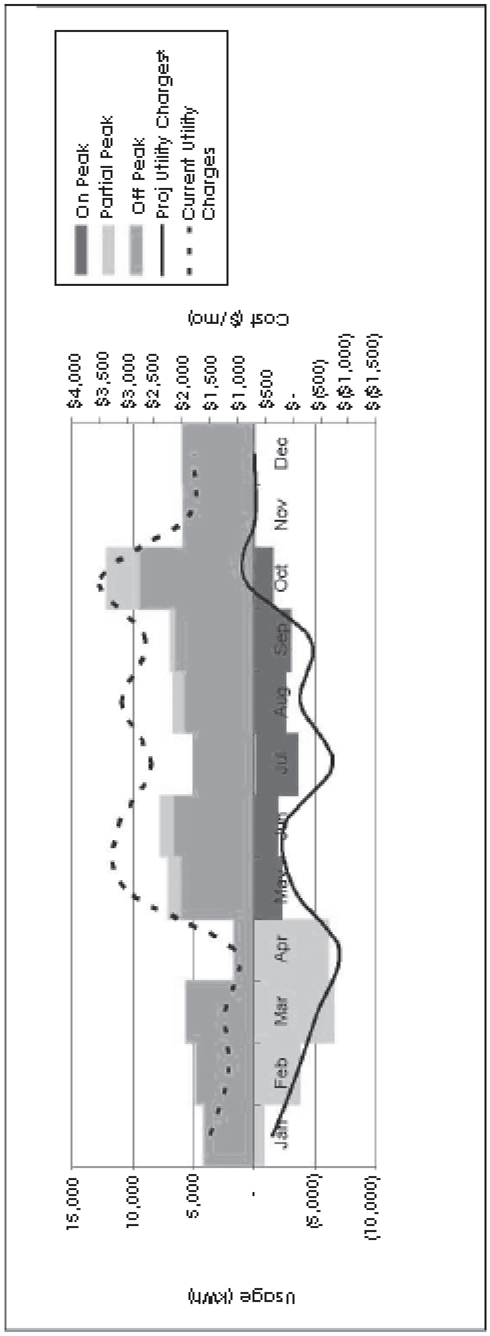

Figure 1. Annual Energy Usage & Billing Estimate with Solar PV Showing Energy Exported for Peak Credit

ing focus at this stage was on the mounting system and the "balance of system" components that interconnect the array, inverters and grid connection.

Ground Mounted Array Design

The District had determined early in the process to utilize a ground-mounted array rather than a building-integrated design (see Figure 2). Three areas on the District's land were identified as potential sites.

EI Solutions hired a soils engineer to assess all three sites. All three sites presented a challenge to the installation of the array. The pump station is located on the shores of San Pablo Bay, and the soil is what is known locally as "bay mud." Bay mud is an unstable and dynamic soil type common to shoreline regions in the Bay Area. EI Solutions' engineering team developed a grade-beam foundation design to minimize potential problems resulting from uneven settling of the soil beneath the array structure. A site close to the pump station was selected as the best site for the installation.

Data Acquisition & Logging System—A Long Distance

The District required a data acquisition system (DAS) and data logging system to be installed for performance monitoring. The DAS

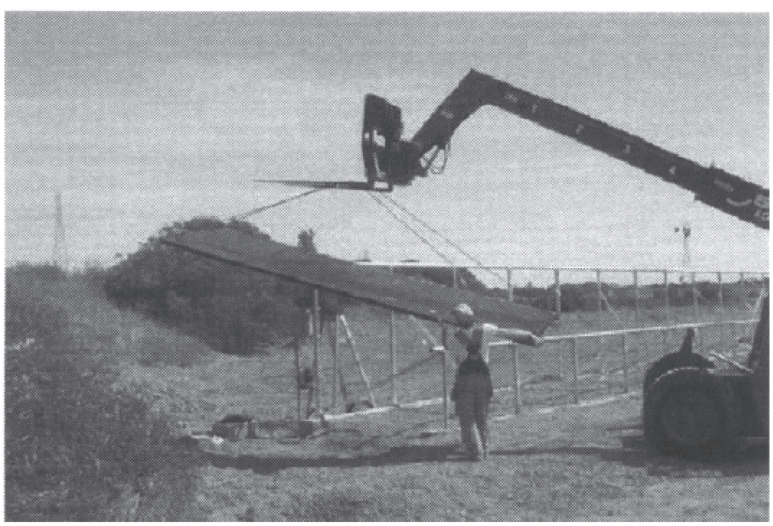

Figure 2. Array Under Construction

provides real time and historical tracking of environmental and performance sensor data. The system enables EI Solutions' engineers to track the system's historical performance against a projected baseline remotely over the Internet. It also provides a real-time dashboard for District engineers to review system status and faults (see Figure 3).

The system site was located about 1/2 mile from the District's offices. There were no telephone lines or data networking connections available at the site for communication between the sensors, DAS and logger. EI Solutions evaluated two wireless approaches to solve the communication problem: (1) using a wireless LAN (802.11 standard) architecture to provide a connection between the DAS and the District's data network, or (2) using a wireless modem to connect the sensor package to the DAS/logger located in the main offices. The latter solution was chosen based on the assessment that the wireless modem data protocols are more robust and that the technology had been field-tested extensively over the distance required.

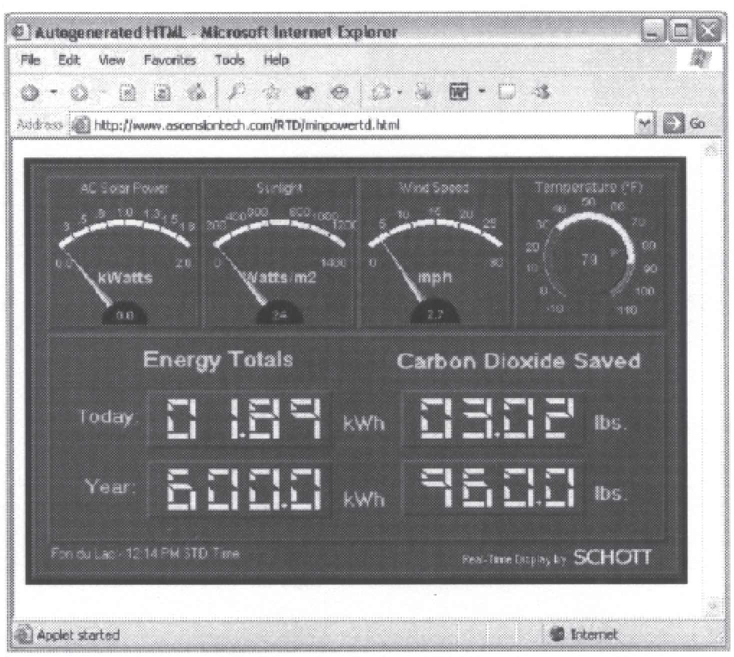

Figure 3. Example Real Time Data Screen

Balance of System: Lifetime Engineering

One aspect of photovoltaic system design that is often overlooked is the balance of system. The reality is that the overall system lifetime is limited by the weakest link in the entire design. Use of inappropriate materials or construction methods can compromise system lifetime. Because a solar power system purchase is typically rationalized using an expected lifetime of 25 to 30 years, the balance of system should be appropriately specified to meet that goal as well as the requirements of National Electrical Code Section 690.

Another key reason to pay attention to the balance of system is to eliminate generation inefficiencies that result from wiring and corrosion problems.

Key specifications for a "best practices" in solar power system design should include the following:

Electrical

- Wire terminations should be minimized to reduce points of electrical resistance
- All circuits should be in metallic conduit, with the exception of intra-module wiring, which may be in free air if USE-2 or equivalent wire is used
- All electrical enclosures should be a minimum NEMA 3R (rain tight) rated or better

Mechanical

- All structural metal components should preferably be stainless steel or anodized aluminum
- Where stainless is not practical, steel components should be electro-galvanized, and all cuts should be treated with a galvanizing compound
- All mechanical fasteners should be stainless steel

SYSTEM COST & FINANCING

The gross cost of the system was $617,000. The system was financed using a rebate from the California Public Utilities Commission (CPUC). EI Solutions accepted assignment of the CPUC rebate so that the District's out of pocket cost was limited to the net cost.

GROSS PROJECT COST	$617,000
CPUC Rebate	($308,500)
NET COST TO DISTRICT:	$308,500

FINANCIAL PERFORMANCE

The system was completed in May 2004. Total construction time was approximately 6 weeks, start to finish. The completed system is shown in Figure 4 and Figure 5.

The system has outperformed projections to date. Payback is expected to be in the originally estimated range of 10 years. The project has an estimated internal rate of return (IRR) of 9%—well above the 2-3% cost of capital for the District. Given the low-risk nature of PV—it has 30+ years of proven lifetime performance—the system is a great financial decision for the District.

"The decision to go solar was a natural one for us," said Megan Clark, board member of Las Gallinas Valley Sanitary District. "Our commitment to the local environment and community is evident in our current pollution prevention and recycling programs. Now we're reducing our impact on the atmosphere by using 100% clean solar energy to

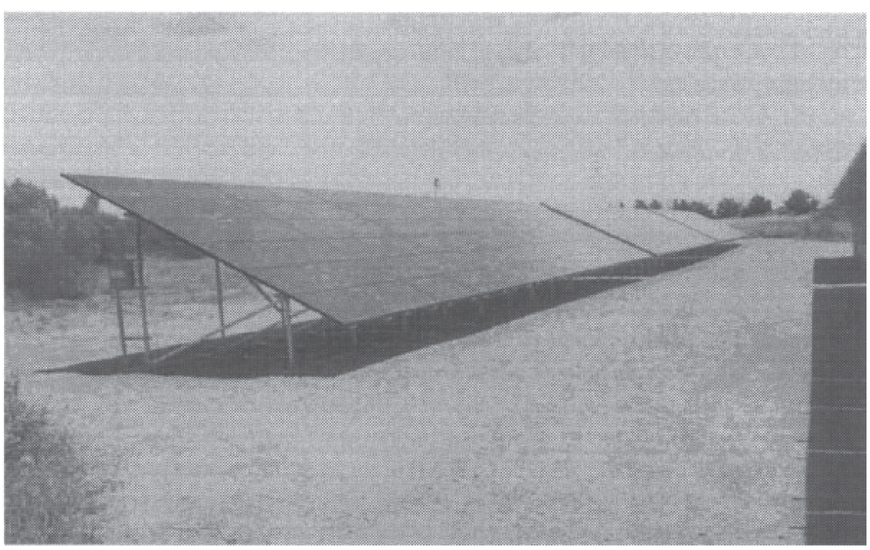

Figure 4. Single Array Row at Ground Level

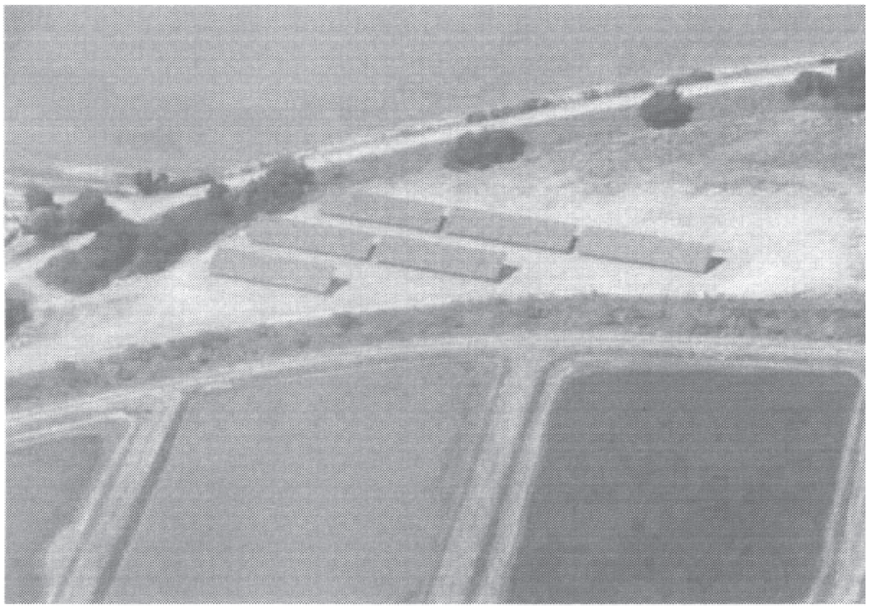

Figure 5. Aerial Photo of Entire Array

power our reclamation pump station. The fact that the system pays for itself made the decision to install the system an easy one."

ABOUT THE AUTHOR

Arno Harris, General Manager, EI Solutions—Arno is an experienced executive with a successful track record of building innovative businesses serving some of the world's most prestigious companies. As the founder of Prevalent Power, Inc. (purchased by Energy Innovations), he brings significant experience in the commercial solar power industry to EI Solutions. He is a founder of two other successful companies, RedEnvelope (NASDAQ: REDE) and Novo Media Group (sold to BCOM3 & Publicis). His background combines marketing, engineering, and consulting with experience servicing such clients as Toyota Motor Sales USA, GlaxoWellcome, MCI, Apple Computer, Hewlett-Packard, Nikon Precision, IKEA International, and NBC Digital Publishing. Arno is a published author, private pilot, and graduate of UC Berkeley. Mr. Arno Harris may be contacted at *arno@energyinnovations.com*.