Tracking the Sun for High Value Electricity by using Gallium-Arsenide Material

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Abstract: - One of the most promising renewable energy sources characterized by a huge potential of conversion into electrical power is the solar energy. The conversion of solar radiation into electrical energy by photo- voltaic (PV) effect is very promising technology, being silent, clean and reliable with very small maintenance cost and small ecological impact. The interest in the photo-voltaic conversion systems is visibly reflected by the exponential increase of scales in the market segment with strong growth projection for the next generation. To improve its more accuracy and efficiency "GALLIUM-ARSENIDE" material that could make solar PV systems nearly three times more efficient than existing products on the market. The solar cells are called "triple junction cells" and they are much more efficient, because they can be chemically altered in a manner that optimizes sunlight capture. The model uses a sensor- driven window blind that can track sunlight along with "light-pipes" that guide the light into the system.

Keywords: photo-voltaic, reliable, gallium, arsenide, triple junction cells, light-pipes

I. INTRODUCTION

Single-axis trackers have been used productively in photovoltaic systems since the early 1980s. The first large-scale one-axis system – still operating – was a 1 megawatt (MW) system installed by the Sacramento Municipal Utility District at Rancho Seco in 1984. The obvious advantage of one-axis tracking is that 15 percent to 35 percent more energy is produced compared to a stationary array using the same number of photovoltaic modules. Despite this advantage, single-axis trackers enjoyed relatively little market development until the late 1990s because, until that time, the best available commercialized technology was expensive and unreliable. The technology was expensive because separate motor/drive/controllers, or multiple passive actuators, were required for each mechanical row of photovoltaic modules, adding roughly one dollar per watt installed cost and thus negating much of the benefit from increased energy production. As a result, customer demand was low.

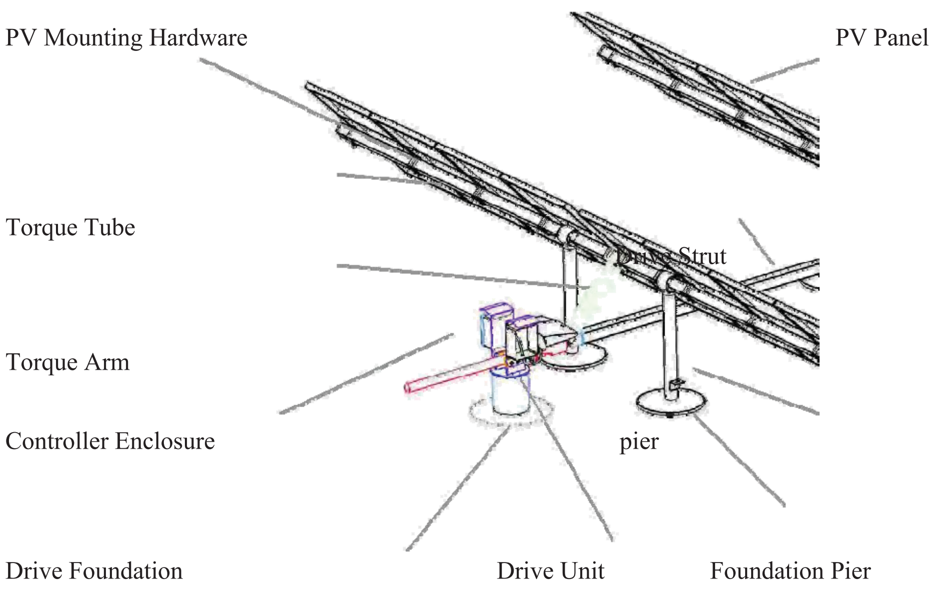
In 1999, Shingleton Design, LLC, developed and introduced the MaxTracker – a single-axis tracker with the potential for low cost and high reliability. This design was literally an application breakthrough. Using a simple mechanical linkage, a single motor/drive/controller could track up to 24 rows – more than 150 kilowatt (kW) – of photovoltaic at one time. With this technology, a customer can reliably track the sun for about the same cost as installing a fixed array. From 1999 to 2003, 6.7 MW of MaxTrackers were installed in the United States, with more than 2 MW installed in California alone. By contrast, less than 4 MW of all competing, one-axis tracker technologies have been installed over the 20 year period of 1984 to 2003. In 2002, PowerLight Corporation acquired ownership of the MaxTracker design, which was subsequently renamed the PowerTracker® system.

The PowerTracker structure, covered by US Patent No. 6058930 with additional patents pending,consists of high strength steel torque tubes and support posts, an industrial drive system, controller bearings and fasteners. The parts count has been kept low to minimize inventory and procurement costs. For any given project, a combination of these components are arranged to the system specific characteristics, including the number of PV modules, the module type and size, the design wind speed, seismic and soil conditions, and the site configuration. Although the basic components are simple, many sites require custom engineering and design elements that add extra costs and delivery time.

The Power Tracker design represents a breakthrough in solar tracking systems by allowing a large number of photovoltaic (PV) modules up to 250 kilowatt-peak to be actuated with a single motor and controller. For minimal incremental cost of the controller and actuator, 15 percent to 35 percent more energy is produced compared to a stationary array using the same number of photovoltaic modules.

II. PURPOSE

This project is to improve the reliability and reduce installation time, maintenance time, and capital cost of the Power Tracker system for utility and other large-scale commercial applications.



Objectives

The following specific measures for this project include:

- Reduce Power Tracker life cycle cost.
- Reduce cycle time from system design to installation.
- Improve reliability and durability.

- Reduce steel waste stream.

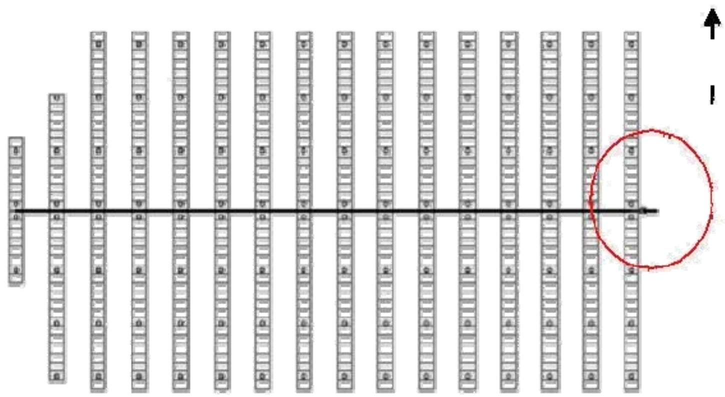


Fig: 125kw power tracker array.

III. WIND AND STRUCTURAL ANALYSIS

The Power Tracker system design varies depending upon the site conditions. The height of the PV above the ground may be as low as 4' or as high as 12' when installed over parking areas to provide shade. Row spacing also varies depending upon the available space and optimization of shading losses as it affects system economics. In addition, sometimes fences are installed around the tracker systems. Some other parameters are variable due to the function of the system and the nature of wind, such as the PV tilt angle and wind angle of attack. PV tilt angle changes throughout the day as the system tracks the sun, and the wind may come from any direction. All of these variables have an impact on wind performance. The wind tunnel test program included a sensitivity evaluation through wind tunnel testing.

The test program, summarized in Table 5, included evaluations of seven system configurations, labeled A-G. Fence types are defined as follows: Type 0 indicates no fence was present; Type 1 indicates a fence was present; Type 2 indicates that a fence was present and an additional diagonal fence was placed at the corners of the array. Exposure relates to surrounding terrain. As defined by the American Society of Civil Engineers (ASCE), Exposure B is applicable to urban, suburban or wooded areas, and Exposure C applies to open terrain with scattered obstructions, having heights generally less than 30 feet including grasslands.

Wind Tunnel Test Program for Power Tracker System

Test Configurations for Geometry A

Configuration	Pier Height	Row Spacing	Fence Type	Exposure
A	4 ft	15 ft	0	C
B	4 ft	15 ft	1	C
C	4 ft	15 ft	2	C
D	4 ft	11 ft	1	C
E	4 ft	7 ft	1	C
F	8 ft	15 ft	1	C
G	12 ft	15 ft	0	B

Source: Power Light Corporation

Other parameters may also vary, such as local wind speeds, surrounding terrain, PV module size and shape, row length, system size, and the shape of the array. The impact on wind loads due to variations in all of these parameters can be evaluated analytically using fundamentals of fluid dynamics combined with wind design standards such as the American Society of Civil Engineers wind design standard (ASCE 7-02). The ASCE-based equations that were used to apply the wind tunnel results are presented in the Project Outcomes

The approach used to evaluate the wind loads on the Power Tracker was to create 1:20 scale models of a basic building block similar to the array shown in Figure 3-3. A photo of the scale model tested in the wind tunnel

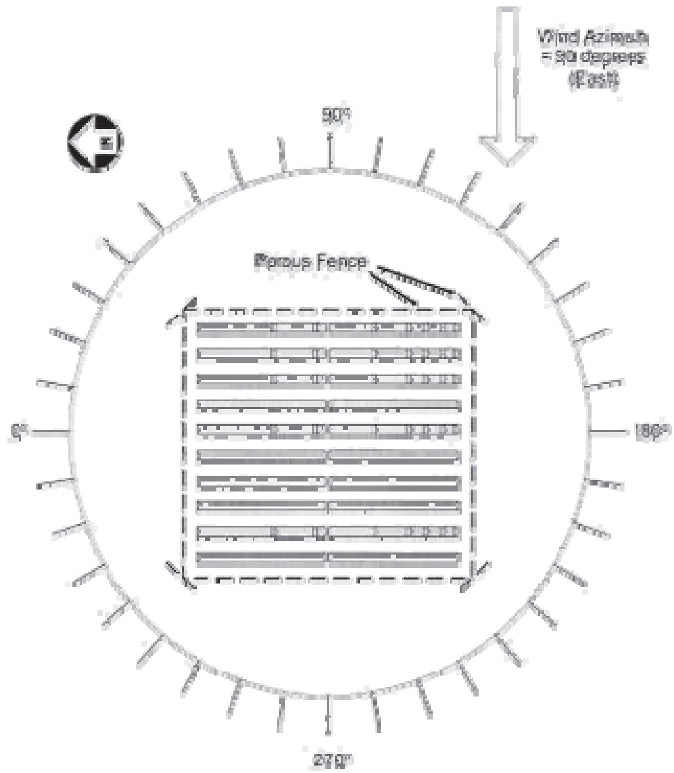


Diagram showing model array and wind direction

PV Mounting Hardware

Various methods for mounting photovoltaic (PV) modules to the Power Tracker system have been implemented in past years with varying degrees of success. Due to the unique geometry of the Power Tracker system, most of these methods were non-standard based on the specific module manufacturer’s recommended mounting methods. In addition, special precautions had to be taken to ensure that no mechanical interference occurred during operation, as the tracker is a dynamic system. The authors’ approach was to evaluate all the mounting methods used to date, focus on the concepts that worked best, and improve them for future use.

The designs of the PV mounting assembly are governed by the following factors:

1. Cost (Labor and Materials)
2. Aesthetics
3. Compatibility with various PV modules
4. Structural integrity over design life
5. Electrical safety over design life

PV Frames

Because of the diversity of PV frame styles, it is difficult to develop a single method of securing the modules to the 4” structural “torque tubes” used in the Power Tracker system. Power Light developed two mounting assemblies in order to accommodate conventional PV module frame designs that employ either internal or external flange frames (IFF and EFF, respectively), as shown in Standardizing this mounting hardware reduces engineering time required for each installation, regardless of the PV module selected.

Figure 3-7. PV Module Frame Types

Source: Power Light Corporation

Test Rig

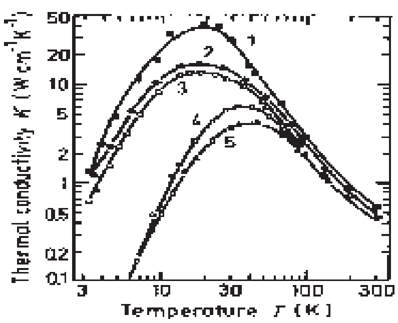
In order to test hardware prototypes, the research team constructed a structural test rig in Power Light’s engineering shop, as shown in The research team built an operational, full-scale section of the Power Tracker system, enabling researchers to simulate field conditions
accurately. The research team has used this test rig to model numerous modifications to the tracker system.

Power Tracker test rig in Power Light engineering shop

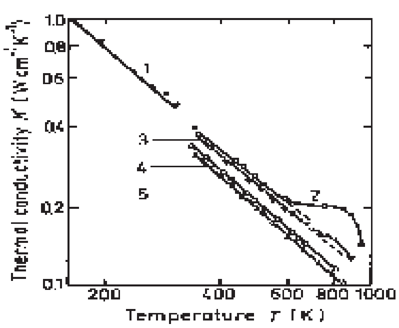
Photo Credit: Power Light Corporation

Thermal properties

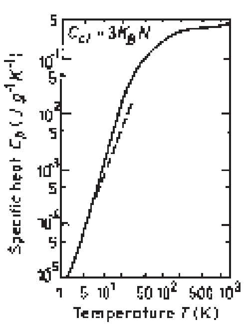
Bulk modulus	$7.53 \cdot 10^{11}$ dyn cm^{-2}
Melting point	1240 °C
Specific heat	0.33 J g^{-1}°C^{-1}
Thermal conductivity	0.55 W cm^{-1} °C^{-1}
Thermal diffusivity	0.31cm^{2}s^{-1}
Thermal expansion, linear	$5.73 \cdot 10^{-6}$ °C^{-1}



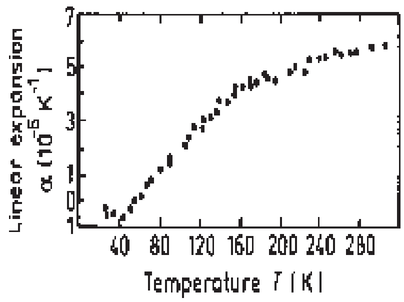
Temperature dependence of thermal conductivity
n-type sample, n_o (cm^{-3}): **1**. 10^{16}; **2**. $1.4 \cdot 10^{16}$; **3**. 10^{18};
p-type sample, p_o (cm^{-3}): **4**. $3 \cdot 10^{18}$; **5**. $1.2 \cdot 10^{19}$.



Temperature dependence of thermal conductivity (for high temperature)
n-type sample, n_o (cm^{-3}): **1**. $7 \cdot 10^{15}$; **2**. $5 \cdot 10^{16}$; **3**. $4 \cdot 10^{17}$; **4**. $8 \cdot 10^{18}$;
p-type sample, p_o (cm^{-3}): **5**. $6 \cdot 10^{19}$.



Temperature dependence of specific heat at constant pressure $C_{cl} = 3k_bN = 0.345$ J g^{-1}°C^{-1}.
N is the number of atoms in 1 g og GaAs.
Dashed line: $C_p = (4\pi^2 C_{cl} / 5\theta_o^3) \cdot T^3$ for $\theta_o = 345$ K.



Temperature dependence of linear expansion coefficient α

Melting point	T_m=1513 K
For 0 < P < 45 kbar	T_m= 1513 - 3.5P (P in kbar)
Saturated vapor pressure	(in Pascals)
1173 K	1
1323 K	100

IV. CONCLUSIONS

This effort has improved single-axis PV tracking technology by increasing the quality while driving costs down, leading to the creation of more renewable options for California energy consumers. To achieve these goals, Power Light adopted a holistic approach to product improvement. As such, this contract covered the full range of activities related to ground mounted solar tracking systems, including:

- The drive unit and controller.
- Tools for design automation and performance analysis.
- Tracker structural design.
- Documentation and product certifications.
- Electrical system design.

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