Optimizing Solar Thermal Performance with Data Loggers

HOBO®
Data Loggers

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Introduction

Solar thermal energy appears poised for a renaissance in the United States, as the Obama Administration presses forward with its green energy agenda. But the revival could be short-lived unless solar hot systems are maintained properly.

Consumers still remember problems associated with solar systems that were purchased during the green energy boom of the Carter Administration. Too often units were either installed incorrectly or never maintained. Energy savings were promised, but not delivered.

Today, solar thermal systems, with the help of portable data loggers, can be optimized to deliver the financial benefits residential and commercial users hope to achieve through their investments. This paper details how solar installers and engineers use data loggers to measure performance of solar thermal systems, pinpoint any defects or inefficiencies, and optimize performance for greater return on investment.

How solar thermal systems work

A typical household solar hot water system pumps fluid through solar collectors on the roof, which captures heat from sunlight and warms water in an insulated solar storage tank. Water from the solar storage tank flows into a conventional hot water heater. Since the solar-heated water is hotter than the normal cold-water supply, the conventional heater uses less electricity or natural gas than it would if it operated independently. By offsetting use of natural gas or electricity, the solar system reduces the customer's utility bill.

History and trends

The concept of solar heating goes back to the 1760s when Horace de Saussure, a Swiss naturalist, invented a hot box that is the prototype for today's systems. In the late 1800s and early 1900s several patents were filed for solar hot water systems that led to widespread use of the technology in states like California and Florida. However, the boom ended in California after natural gas became abundant in the 1920s and 1930s and in Florida when central-plant electricity came to dominate following World War II. [1]

Solar thermal collectors produced an estimated 165 GW last year in 49 countries that represent 60% of the world's population, according to Solar Heat Worldwide, a report published in 2009 by the International Energy Agency. The US continues to lag behind China, Turkey, Germany, Japan, Israel, Brazil, Greece and Austria in use of the most common solar hot water heating technologies: flat-plate and evacuated tube collectors. [2]

However, US installations have increased rapidly over the last decade. From 2007 to 2008, alone, solar water heating system shipments grew by 50%, bringing the total number of systems installed to 20,500, accounting for 485 MW. Given that the nation has 80 million detached single family homes, the potential for solar thermal growth is enormous.

The US industry is forecasting even greater market expansion because of the American Recovery and Reinvestment Act. The act expands a federal investment tax credit for homeowners by removing its $2,000 cap. The incentive is available through 2016. [3]

Payback

Solar hot water is considered to be one of the most cost-effective forms of renewable energy. In Florida, a national leader in solar hot water use, the technology reduces a homeowner's annual electric bill 15% to 30%. [4] Payback on a system varies depending on a variety of factors, including the electric or gas rate charged by the local utility and availability of government subsidies. Payback can be immediate for a new home, if homeowners incorporate the cost into their mortgage. [5]

Innovations

Heating water for homes and swimming pools continues to be the dominant use of solar thermal technology; space heating and cooling remain relatively uncommon. The US, however, is seeing an uptick in space heating, particularly for commercial enterprises, such as offices, apartment complexes and hotels. Fletcher, North Carolina is home to one of the largest commercial solar thermal installations in the world. The Fletcher Business Park, which includes warehouses and offices, has 640 solar thermal rack-mounted roof collectors that provide thermal heating and cooling. Solar thermal also has strong potential in agricultural or food industries, such as poultry processing, which uses large amounts of hot water.

For the future, solar hot water systems are increasingly being discussed by energy planners as a way to help manage overall electric load on the grid. Utilities would aggregate solar load and employ it as a demand reduction tool. So, if large numbers of homeowners use solar, rather than grid electricity, to heat hot water, and they do so around the same time of day, the utility can back down power plant operations.

[1] California Solar Center, Solar Evolution: The History of Solar Energy," www.californiasolarcenter.org/history_solarthermal.html

[2] While the US falls behind several nations when it comes to domestic solar hot water, it is a leader in swimming pool systems. The IEA estimates that US solar thermal swimming pool systems, which typically use unglazed plastic collectors, account for 19 GW.

[3] Solar Energy Industry Association, US Solar Year in Review 2008, www.seia.org/galleries/pdf/2008_Year_in_Review-small.pdf

[4] Florida Solar Energy Center, www.fsec.ucf.edu/en/consumer/solar_hot_water/q_and_a/savemore.htm

[5] US Department of Energy, "A Consumer's Guide: Heat your Water with the Sun," www.nrel.gov/docs/fy04osti/34279.pdf

Solar hot water also is increasingly viewed as a way to generate renewable energy certificates. Also called green tags, they monetize green energy use and can be sold to utilities and retail suppliers in states that have passed laws requiring that a portion of electric power come from renewable energy. RECs can create a revenue source for solar system owners.

Data loggers in the solar thermal market

Data loggers are tools that can help spur greater adoption of solar hot water technology. Engineers and solar installers use data loggers to detect system problems and make corrections that maximize system performance. Better performing systems create more energy savings. Customers, in turn, are satisfied and the technology's reputation is enhanced, encouraging more installations.

With data loggers, solar thermal system problems often can be identified by measuring and recording the following:

- **The temperature in the storage tank**
- **Current in the back-up water heater**
- **Current in solar pump**

Portable data loggers, such as those developed by Onset®, lend themselves to easy gathering of this information because they are small, portable and a fraction of the cost of wired sensors. By applying data loggers to these points on the system, a solar hot water installer can fine-tune the system and/or correct problems that cause inefficiency. Equipment may have been installed incorrectly or the system may lack insulation, causing heat loss. Based on information captured from the data loggers, installers might remove trees that shade the roof, re-route pipes, adjust temperature regulators, cover pipes or insulate tanks to improve system performance.

Richard Reis, PE (www.conservationengineering.com) used a portable data logger to uncover problems, identify solutions, and improve system performance. (See figure 1). He logged when the pump turned on and off and graphed the temperature at the top of the storage tank and current of the back-up heater.

The system was short cycling, he discovered, because the pipes that supply and return the fluid to and from the collectors were reversed. The solar pump ran for a very short time as the sun heated the collector (and the nearby pipe and sensor), then turned off as soon as the relatively cooler fluid was pumped by the sensor. It then repeated the cycle. He corrected this problem, as well as made other improvements, such as wrapping tanks with insulating blankets and increasing the temperature cut-off control temperature. (See www.solartoday.org/waterheating/ for more information on this system, its instrumentation and data plots.)

With better performance, the system reduced the average electric bill from 800 to 300 kWh. Federal and state incentives helped the system provide an attractive four-year return on investment.

Data loggers also play an important role in helping customers see, in black and white, the energy savings they have achieved with solar hot water. Tom Wineman, president of Clean Energy Design, www.cleanenergydesign.com, has seen a shift in consumer interest from straight forward solar installations that heat hot water to more complex systems that also offset part of the building's conventional heating. Wineman finds that customers who install these more complex systems want to know that their investment is producing promised results. Data loggers allow him to demonstrate how much fossil fuel the system offsets at any given time.

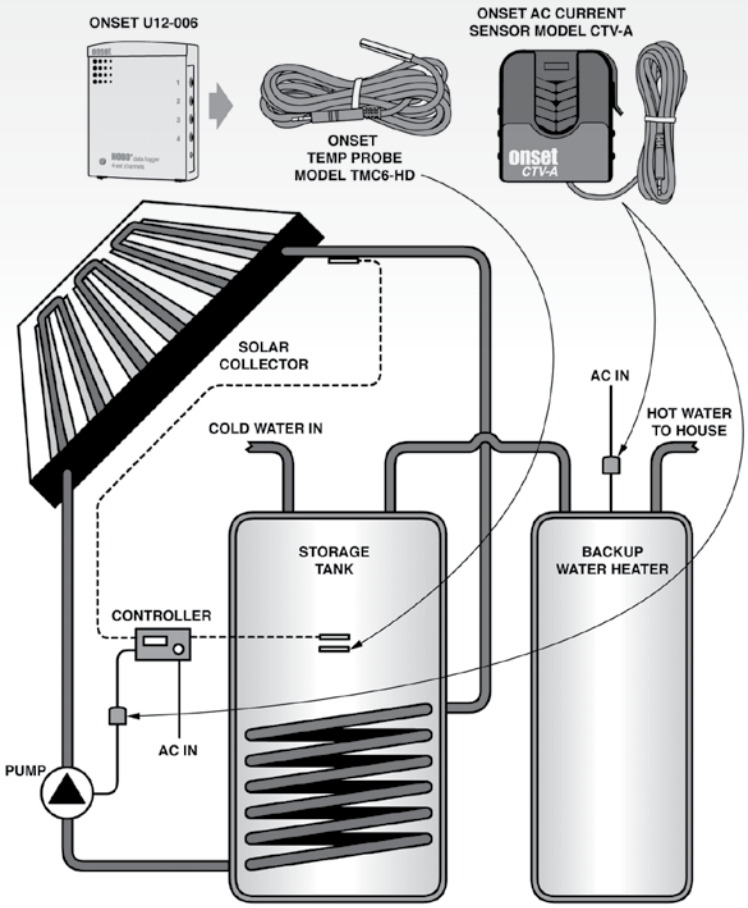

Figure 1. Data loggers can pinpoint solar thermal system performance by measuring storage tank temperatures, and AC current in the back-up water heater and solar pump.

The key, he says, is to measure thermal gain in the tank. To do this he measures the temperature of the water from the street, the delivered system water temperature, flow, and output temperatures to determine the delivered BTUs or kilowatt hours.

To uncover any problems in system performance, Wineman measures input and output temperature from the solar storage tank to the roof. "I measure multiple points, but

typically input and output temperature from the roof to the storage tank. Along with the corresponding pump run time, it tells you what kind of thermal heat gain you are getting from the panels. Mostly you are showing overall thermal performance over time," he said. If he finds an excessive rise in temperature, he might adjust flow through the panels.

Without the kind of feedback offered by data loggers, customers may be unaware that minor repairs can lead to major energy savings. "I've seen systems orphaned because there was no one familiar with how to maintain them," Wineman said. "I have restored systems that were abandoned for years, just for simple stuff -- lack of a simple circulator pump or control which any plumber is capable of fixing."

How data loggers work

Data loggers are battery-operated, standalone measurement tools containing a microprocessor, memory, and sensors for measuring and recording one or more variables over time. Some data loggers have internal sensors, so that measurements can be made within the logger, while others rely on sensors on external cables that allow for monitoring at some distance from the data logger itself. [*Minor change to reflect loggers such as the U12-012 that do both.]

A data logger may offer a combination of internal and external sensors, as well as external channels accepting pulse, 4-20mA or DC voltage inputs from other sensors for even greater flexibility. The loggers operate unattended for hours, days, or months at a time.

Specialized software is used to configure the logger (select sampling intervals, synchronize logger and computer clocks, etc.) and to off-load the recorded data from the logger to a PC or Mac for graphing and analysis. To configure the data logger, the user simply connects the data logger to a PC or Mac via a USB cable and the accompanying logger software automatically recognizes the device and asks a series of configuration questions. The user then chooses a sampling interval and selects an immediate or designated future launch time. There is no programming involved.

Once data has been collected, the data logger is reconnected to the computer and the software converts the information into time-stamped graphs. The data can be analyzed with the provided software, or easily exported into Microsoft® Excel or other spreadsheet programs for further analysis.

It is important to note that, in addition to data loggers that communicate with computers via USB, there are a number of web-based data logging options available that provide users with convenient access to real time data remotely over the Internet.

Conclusion

Easy-to-use data loggers can measure and monitor solar thermal system performance, allowing installers to correct mistakes and fine-tune system performance. As a result, US consumers are likely to regain confidence in the technology, spurring what is expected to be a burgeoning market for solar hot water heaters.

About Onset

Onset Computer Corporation has been producing small, inexpensive, battery-powered data loggers and embedded controllers since 1981, and has sold over one million loggers that are used around the world by over 50,000 customers. The company manufactures a broad range of data logger and weather station products that are used to measure temperature, humidity, light intensity, voltage, and a broad range of other parameters. Onset products are used widely in research, commercial, industrial, and educational applications.

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