Internet Based Inverter-Integrated Solar Power Meter System

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ABSTRACT

The cumulative capacity of installed solar electric systems in the United States is expected to grow substantially from less than 0.4 GW in 2003 to 200 GW by 2030.[1] In order to efficiently track the performance of these systems it will be necessary to deploy and unprecedented number of monitoring systems that are simple, effective, reliable and versatile. PV Powered has developed a low-cost, easy to deploy and dependable inverter-integrated metering system that is able to collect, process and present information to help users monitor and evaluate their photovoltaic energy generators. With this system the people who need information will have remote and local access to useful data through an internet based interface that allows users and providers of managed services to quickly spot performance issues, improve maintenance effectiveness and monitor the environmental contributions of using solar energy.

Keywords: solar, monitoring, meter, energy, internet

1 SYSTEM DESCRIPTION

The meter system consists of a data gathering and communication interface module, called the PVM1010, a relational database on a remote server operated by PV Powered, a browser-based user interface developed by PV Powered and a user supplied local area network connected to the internet using a broadband connection. The PVM1010 module collects and translates data from the inverter for transmission over the internet to the server where the data is archived in a secure database for access by authorized users who operate a web browser to view their information wherever they have access to an internet connection.

1.1 Data Communication Module

The PVM1010 is the first data monitoring device on the market that is designed to be installed directly inside a solar power inverter and provides a standard interface for internet bound communications. It connects directly to the serial interface of the inverter to receive power and communication signals using a proprietary protocol to protect access to other vital inverter commands. On the network side of the PVM1010 there is a standard Ethernet interface for connection to the local area network (LAN). In systems with multiple inverters, each inverter is connected by Ethernet cable to the router. This approach makes it easy to add or remove inverters from the system without disrupting the reports of other inverters.

Installation of this UL listed interface module inside the inverter enclosure provides a reliable direct connection to the inverter as well as protection from environmental hazards. Because the information is obtained directly from the inverter processor and associated sensor hardware it is possible to continuously gather very accurate operational data without the need for additional current sensors and signal processing circuits that could introduce inaccuracies, extra cost and complexity. The total energy production reported through the PVM1010 module is identical to the readings shown on the display panel of the inverter so the user can be assured that the total energy produced by the inverter is the same as the value being reported to the database on the remote server.

1.2 Remote Server

The PVM1010 sends out XML based data packets at 15 minute intervals for storage in a database on an off-site data center server. The packets of information from the inverter contain inverter data such as serial number, energy production, voltage levels and system status. When received at the server, the data is stored as a record in the user account that is associated with the inverter. A continuous record of inverter operation is kept in the server for analysis along with reporting of trends and performance statistics. The system is secure because only outbound traffic is generated by the PVM1010 and access to the database is dependent on password protected user accounts. No special system configuration steps are required by the user and the use of dynamic IP addresses is allowed due to the use of DHCP.

1.3 User Roles

Various arrangements of information and content can be created for different kinds of user situations because a web page interface operating on a standard browser is used. The types of roles that have been identified are: end user, installer, kiosk and administrator. For example, an end user role has the ability to see basic monitoring information about their system but their installer may have a more detailed view of fault information and inverter

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performance to aid in troubleshooting activities. The administrator role has control of detailed account profiles and installation specifications along with access to specialized inverter readings used in analyzing abnormal system operation. For situations where a public display is needed there is a kiosk role that shows selected information for consumer education, brand image marketing or details about an installation that might be useful for gaining insight into operation trends. As the market for solar power monitoring evolves it is expected that a wider range of roles will be created to make use of a common database for the specialized needs of certain types of users.

1.4 Data Visualization

The presentation of data and statistics for the various roles is critical to how well the user experiences and understands the information being displayed. The use of web browser technology allows the creation of various types of information frames that can be arranged to suit the overall viewing situation. For example, a frame can show a trend line graph of power output which is a good way to show the continuous status of the system. Other frames can show bar graphs of accumulated energy production much like a typical energy bill consumer receive each month. Display of comparison data is also useful for detecting how system operation varies from one period to the next. For instance, by looking at a daily power curve of the winter output vs. the summer output may show that a significant amount of shade is present and something needs to be done, such as tree trimming, to recover the lost energy production. In another case, the loss of data due to a communication interruption may be visible when looking at trend charts showing no information for specific periods of time. If this occurs then the user can be encouraged to make improvements in their network infrastructure.

1.5 Metering System

In the energy industry it is traditional to make use of a separate meter device to collect and display energy readings. These separate meters have evolved from complicated electromechanical meters to the modern solid-state intelligent meter devices that are very accurate and reliable. With the introduction of inverter integrated metering it can be foreseen that traditional stand-alone meters may not be needed to report energy production from solar installations if it can be shown that integrated meter systems are accurate and reliable too. It is obvious that the cost of metering will be reduced if a separate meter is not needed at the installation but this will not happen until new test procedures for verifying the accuracy of inverter-integrated meters can be established. To create this new accuracy certification standard it will be necessary for the inverter companies to collaborate with utilities and testing labs to develop new test procedures that are suited to inverter integrated meter systems.

2 BENEFITS

The development of the PV Powered inverter integrated meter system was motivated by the need to provide an economical and effective method of monitoring inverter performance for a large number of installations. With this monitoring solution platform, that uses open standards and off-the-shelf equipment, end users can have a remote view to the operation of their system through common internet services, standard web browsers and existing computers. PV Powered believes that by making it easy to install the interface module on any inverter, thereby enabling automatic transmission of performance information to a secure database, the barriers to adoption of data monitoring services will be minimized. The availability of a browser based user interface with password protected access and easy to understand presentation of measurement data using summary tables and graphs gives the end user confidence that their system is operating properly.

2.1 User Behavior

It is believed that when end users are given convenient access to energy information they will become more aware of their energy usage behavior and take actions to both control energy consumption and maximize energy production. An end user web-page is available that shows energy offset data for how much environmental benefit has been realized for every unit of solar energy production. For example, the display may show how many pounds of CO2 emissions have been avoided or how many barrels of oil have been saved. This information is useful to people who are active in controlling their total carbon footprint. In addition, with a load meter that measures demand from the site, it is possible to determine if there has been net positive energy production from the calculation of solar power produced minus total power being consumed. In some situations, when users know if they are close to exceeding a rate tier they may opt to turn off some equipment and keep their energy bill referenced to a lower cost tier. As consumers become more educated about the relationships between energy consumption and solar power production they will be persuaded to modify their behavior by the information provided from their solar monitoring system.

Feedback from existing customers has shown that many people are curious about the daily operation of their systems and comparisons of results from year to year or month to month. They also want an easy way to know if their system is performing properly relative to expected level of production. Installers have provided useful feedback by asking for better ways to learn about system

faults and troubleshooting techniques so they can minimize service costs and respond more rapidly to problems. When an inverter integrated meter is included with all solar installations and tied to a common information center it will be possible to provide a great deal of real-time and historical performance information to all users and installers to address the questions they have.

2.2 System Productivity

It is assumed that by collecting and analyzing information from a large number of sites it will be possible to evaluate various design, installation and maintenance variables to gain insights into real-world system operation that will lead to improvements in products, technologies and services related to distributed power systems. In a solar installation there are many variables that effect overall performance and system productivity. Using the inverter integrated meter along with other associated sensors it will be possible to monitor for total system efficiency and validate performance guarantees. For instance, the inverter could be made to include DC current sensors to monitor the health of the photovoltaic panels. In addition, the inverter could be used to detect the grid voltage and power quality information and make real-time adjustments to improve system capacity and efficiency. It is also possible for the inverter to be connected to meteorological sensors and make measurements of solar irradiation, temperature and air speed for use in calculating available solar energy and overall system efficiency. By monitoring trends or comparing information from many sites it will be possible to forecast energy production more accurately and to trigger maintenance activities such as panel cleaning or shade removal. All the information collected by the inverter integrated metering system will be stored for later use in a common archive that is shared by many installations and give operators a new and unique view of how solar energy systems behave.

2.3 Reporting Requirements

Since the deployment of solar energy systems is often associated with some sort of economic incentive there are requirements to monitor system performance to be sure the incentives are having the desired effects. There is also an opportunity to report data about production of energy to support the trading of renewable energy credits or to verify energy portfolio requirements. With an inverter integrated meter system and a common database it will be very economical and efficient to pass the necessary information to interested stakeholders. Secure access to the database for users, owners and power purchase agreement holders will be enabled by consensus among industry participants on standard data communication protocols and reliable methods of verifying measurement accuracy. Currently the PV Powered monitoring system is able to collect and hold energy data directly from inverters and export reports in standard file formats. Work is ongoing to collaborate with reporting agencies to develop standards for communication protocols that will make it easy to share data in a secure fashion across multiple organizations that have an interest in performance reporting.

3 CONCLUSION

As solar energy systems become commonplace the benefits enabled by inverter-integrated meters will become a normal expectation of all solar PV installations. The behavior of system owners, service providers, utility operators and equipment providers is certain to change when these people are able to gain real insight into the operation and performance of the solar energy infrastructure. With an internet based inverter-integrated meter system at the heart of each installation, people will take an active role in managing their energy consumption and want to find additional ways to produce more clean energy.

REFERENCES

[1] U.S. Solar Energy Industry Association, “Our Solar Power Future”, 6, 2004

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