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# POWERING HEALTH: REMOTE MONITORING

Remote monitoring of health facility power installations increases the speed, effectiveness, and value of maintenance activities.



## **POWERING HEALTH**

This document is provided as part of USAID's [Powering Health](#) toolkit. Health-care facilities require electricity to maintain perishable supplies and power life-saving technologies. Energy is essential for preventing child and maternal deaths, controlling the HIV/AIDS epidemic, and combating infectious diseases and pandemics.

Reliable electricity can mean life or death for patients in developing country health-care facilities. However, many of these facilities have little or no access to reliable electricity. USAID supports partner countries in understanding the energy needs of their health-care facilities over the long term. This challenge requires local capacity for careful planning, a commitment to maintenance, and dedicated funding.

USAID uses its experience at the nexus of the health and energy sectors to help international development practitioners and health-care administrators design programs that meet the energy needs of health-care facilities. By applying international best practices and lessons learned, stakeholders can help ensure that health-care facilities are able to power standard appliances, such as lights, life-saving equipment, blood and medicine refrigerators, ventilators, laboratory diagnostic tools, and technology that monitors patients' vital signs.

## **INTRODUCTION**

Remote performance monitoring describes an approach to tracking the operation of energy systems or processes, such as the charging and discharging of a battery bank, from a distance. Remote monitoring technology enhances maintenance activities, informs system designers of real-world environmental and operational conditions, and generally promotes the sustainability and reliability of backup power installations.

Remote monitoring is used in a wide range of industries to track the performance of industrial, scientific, and power equipment. This document provides a broad overview of the many commercially available remote monitoring applications, technologies, and techniques that can be used with power installations at health facilities.

## **REMOTE MONITORING APPLICATIONS**

Remote performance monitoring systems are used in a variety of applications and settings. They are often used in the oil and gas industry to monitor leaks in gas pipelines and in the telecommunications industry to ensure cellular towers have backup power. Remote monitoring also is frequently used to track industrial processes and weather conditions. In rural health-care facilities, remote monitoring systems can be used to track a variety of important energy system components described below.

### **BATTERY BANKS**

Critical loads require constant battery backup power in order to ensure a consistent, uninterrupted power supply. However, battery banks are perhaps the most delicate component of a facility's energy system. Some battery chemistries, e.g., flooded lead-acid batteries, also require regular testing and maintenance. Many factors influence the life of a battery bank, including depth of discharge, charge rate, and temperature. By monitoring these variables and making sure that they are all within proper boundaries, problems can be identified before they result in system failure. A battery monitoring system

acts as an interface for the operator, communicating and logging critical information on the status of the battery bank that can help technicians identify problems before they lead to costly battery failures and system downtime. Facility administrators can track the following important parameters through remote monitoring systems:

- State of charge (%)
- Battery bank voltage (volts (V))
- Battery charging current (amps (A))
- Battery temperature (Celsius (C))
- Days since fully charged



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A battery monitor connects directly with a system's battery bank and inverter/charge controller to obtain data on voltage, current, and resistance within the system. Monitoring systems may also be equipped to track specific gravity, electrolyte levels, and temperatures within individual cells. Typically, the monitor will display key information, such as the state of charge of the battery bank, consumed amp-hours, voltage, and remaining battery life. Monitors can also be programmed to issue audible alarms or control other devices automatically when problems occur.

## PV ARRAYS

Photovoltaic (PV) arrays are good candidates for remote monitoring systems. PV arrays are as expensive or more expensive than battery banks and are often used in both critical infrastructure and remote areas without easy access for in-person monitoring. Ensuring that PV arrays are working properly is important. Remote performance monitoring systems can be used to track the following PV parameters:

- Solar charging (kilowatts (kW))
- Solar charging (amps (A))
- Solar radiation (watts per square meter (W/m<sup>2</sup>))

## FACILITY CONSUMPTION

Remotely monitoring actual facility loads is an important part of the energy system design process and subsequent evaluation of energy system performance as it provides real load data to compliment the estimates made through load inventories. For instance, monitoring consumption helps to determine if a battery bank is sized properly. Remotely monitored data provides more accurate information on peak and minimum load values, operational hours, and consumption. Loads can be measured at the facility level or at individual circuits. Data should be logged for a



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number of days, preferably for several weeks. Longer data monitoring sessions add confidence to the results of the load analysis. By tracking loads over multiple days or weeks, it is possible to distinguish between periods of facility operation and downtime, such as days, nights, and weekends.

Remotely monitored load data also verifies and expands on energy audit data that details equipment usage patterns collected from interviews of facility personnel. If sufficient measured data is available, it is preferable to use actual data for analysis purposes, rather than estimated figures. Consumption is usually tracked by the following:

- Current draw (A)
- Load (kW)
- Energy consumption (kilowatt-hour (kWh))

## REMOTE MONITORING DESIGN AND TECHNOLOGIES

The cost, complexity, reliability, and availability of features provided by remote monitoring equipment vary significantly between technologies. Choosing the most appropriate equipment for a specific application requires an understanding of user needs and constraints (cost, power, connectivity, etc.)

There are many methods of conducting remote monitoring, so an engineer must select or design a remote monitoring solution that answers three critical questions:

1. Which on-site hardware will be used to measure and record data?
2. How will data be communicated from the remote site to those who need it?
3. How will remote users interface with data and consume it?

The following sections discuss the possible technological solutions underlying each of these questions.

### ON-SITE HARDWARE

The hardware installed at the target installation site is the heart of the remote monitoring system, generating, storing, and transmitting a flow of data. This hardware is made up of sensors, data acquisition systems, and communications equipment that must interface with one another and the energy system hardware itself (e.g., inverters, charge controllers). When specifying the on-site hardware of a remote monitoring system, compatibility is the key issue. The installed systems must be able to communicate with one another in order to relay performance data to a remote location.

The most effective on-site hardware configuration depends largely on the brand of inverter or charge controller used. Different brands utilize different communications protocols when communicating data. In many cases a proprietary protocol is used, but some brands utilize open-source protocols that allow more design flexibility for remote monitoring systems.

How the remote monitor interfaces with inverters, charge controllers, computers, or other machines is another important consideration influencing the on-site hardware selection. These communication interfaces are usually accomplished with serial ports, such as the RS-232 port, RJ45 jacks used by ethernet cables, or USB ports. To a large extent, both the communications protocol and interface will define the complexity of the remote monitoring hardware configuration.



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## POWER SUPPLY

Determining the source of power for the remote monitoring hardware is an important first step in understanding the system's design constraints. As more frequent transmissions require more power, the availability of power will have an impact on the frequency of data logging and data transmission. Many remote monitoring systems rely on solar panels to provide power, as they are typically deployed in locations far from other power sources. Other sources may be utilized, such as an auxiliary power supply on an inverter.

## SENSORS

Sensors are devices that measure system performance or environmental parameters and convert that measurement into a form that a data monitor can interpret. Sensors are available for tracking any number of specific conditions, such as water flow, air speed, and voltage. In an off-grid solar installation, system parameters of interest will include DC voltage, solar irradiance, the battery bank's state of charge status, system demand, etc. Many types of system components, notably inverters and charge controllers, already are able to track basic electrical parameters such as voltage and amperage, so many of the sensors needed for remote performance monitoring are already integrated into the system. Additional sensors may include the following:

- Solar radiation sensor
- Kilowatt-hour logger
- Battery temperature monitor



JOSEPH OWEN ROBERTS / NREL

## DATA ACQUISITION

The data acquisition (DAQ) hardware, also called a data logger, is a key component to nearly any remote performance monitoring system. Depending on the complexity of the DAQ, it can receive, store, and transmit data from the numerous sensors and system components such as the inverter and charge controller. A data acquisition system may consist of more than one piece of equipment. An engineer has three basic hardware options to remotely monitor a health-care facility energy system: built-in DAQ systems, a dedicated personal computer (PC), or a third-party data logger.

Many solar system equipment manufacturers, such as inverter manufacturers, include data acquisition hardware in their equipment. The capabilities of these built-in DAQ systems vary from manufacturer to manufacturer and may include such features as internet connectivity, display screens, or additional data storage capacity.

Alternatively, a dedicated PC can be used as DAQ hardware provided that sensors are able to connect to the PC. Some companies provide USB-based sensor ports and software that can manage, store, and communicate sensor data onto a PC hard drive. These options present relatively low-cost ways to collect and share large volumes of information.

The last option that an engineer can use to remotely monitor an energy system is a third-party data logger that monitors, stores, and transmits system performance data. These systems differ from PC-based systems in that they are robust and specialized pieces of equipment designed to efficiently record data. This makes them generally more reliable, more energy efficient, and smaller. They typically do not communicate directly with energy system hardware, meaning that they cannot record data from any of an inverter's built-in sensors or alarms. Third-party data loggers are most commonly found in industrial settings, and many are designed for specific tasks (e.g., wind speed measurement or kWh logging). More versatile systems can be configured for a wide range of sensor types, but are often comparatively complex. While generally more reliable than PC-based systems, third-party data loggers are also more expensive.



HERMAN CHAN / NREL

## COMMUNICATIONS

If a DAQ system lacks a way to communicate data to the computer of a distant observer, then it is not able to provide remote monitoring capability; technicians must periodically return to the system and retrieve recorded data. This incurs significant time and expense that would be avoided with data transmission capability. Modems are the basic device that allows communication with the outside world. System designers have the option to pick the medium (telephone lines, cellular networks, satellite links, etc.) that the modem will use to transmit data. When choosing an appropriate communications medium, reliability should be the key criteria.

In most cases, communication through the internet is an easy, cost-effective, and versatile approach. The alternative is to build a physical or wireless link from the remote location to the observer's computer, often at great expense. As internet infrastructure is found almost everywhere, it is much cheaper to simply build a single communication link that connects to preexisting internet infrastructure. This single communication link can be wired, cellular, or satellite. However, the reliability of an internet data link is dependent on the condition of available communications infrastructure and access to information technology (IT) management.

## MODEM

A modem is a device that transmits data supplied by a DAQ over a specific medium. For most remote health-care facility energy systems that medium will be radio waves, but it is possible to use phone lines if the facility has a landline connection.

## WIRED CONNECTION

Wired internet connections are a low-cost option for transmitting large amounts of data via poles and telephone lines. The availability and reliability of such connections depend largely on the state of local infrastructure. Most remote health-care facilities, especially those that are off grid, will not have the wired telephone connections required for this type of connection. These systems also are vulnerable to natural disasters or other interruptions of service.

## CELLULAR CONNECTION

A cellular internet connection is another data communication option. The reliability and performance of a cellular connection depends largely on the cellular signal strength at the installation site, which varies based on the local carrier (service provider) and cellular technology. These systems are also subject to interruptions of service due to natural disasters. The necessary hardware, network settings, and contract type may differ from one carrier to the next, making the standardization of remote monitoring systems across multiple locations difficult.

## SATELLITE CONNECTION

Satellite-based internet connections are an option that is especially appealing for rural installations that do not have access to wired or cellular internet connections. This type of connection is typically more expensive, but the final cost will depend on the amount of data being transferred. These connections are reliable and are normally unaffected by natural disasters. Setting up such systems, however, can be more complicated and expensive than setting up a wired or cellular connection. Satellite internet connections, for instance, require a very-small-aperture (VSA) satellite dish (like those used for satellite television) on site; incorrect installations can lead to reliability issues in satellite-based internet connections.



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## RADIO CONNECTION

Radio connections use unlicensed bands of radio-wave spectrum to transfer data between points. One of the most common ways to transfer data via radio on an unlicensed spectrum is through the Institute of Electrical and Electronics Engineers (IEEE) 802.11 communication protocol, which is the basis of Wi-Fi. Radios are frequently used in remote monitoring applications because they provide a consistent and robust way to transfer data wirelessly, independent of internet and satellite service providers, local infrastructure, and service fees. The hardware associated with a data radio network includes a radio, a radio modem, and an antenna not only for the installations being monitored but also for a base station that would receive and remotely store data. The range, reliability, and transmission quality of such a network depends on the quality of the hardware used, the transmission power, the protocol used, and the availability of uncongested, license-free radio frequencies.



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## **USER INTERFACE**

The final critical component of a remote monitoring system is the user interface. The DAQ at the remote site transfers its data to a server that stores and possibly processes the remote monitoring data for a technician to interpret. This data server may be owned by the organization responsible for monitoring the health-care facility, the manufacturers of the energy system equipment, or a third party.

## **FTP SITE**

File transfer protocol (FTP) sites are a convenient way to store raw, pre-analyzed data away from the remote location where the data is generated. Technicians can then access the FTP site at their leisure to download and analyze system performance data. An FTP site can be run on a server owned by a third party or by the organization responsible for monitoring the energy system performance. System administrators and other authorized parties can access the data from anywhere. Once the data is downloaded, the technician must still analyze the data in order to know if the system is operating normally or if a problem has occurred.

## **MOBILE APPLICATION**

DAQ systems can communicate with third-party servers that provide automated analysis of the data. Technicians can use mobile applications on smartphones, tablets, or other mobile devices to access the results of the analysis. Such applications provide technicians and administrators the ability to check system performance from virtually any location. They may also issue alerts or alarms when system failures occur or, better yet, before they occur.

## **PERIODIC REPORTS**

Not all system stakeholders are concerned with real-time data analysis. Some are more interested in overall system performance and sustainability. Periodic reporting of system data (on a weekly or monthly basis, for example) is made possible through remote monitoring. Performance data over the period can be graphically represented for easy interpretation, and a discussion or analysis of that data may also be included. Such reports can be automatically generated and sent via email or prepared by system managers.

## **PUBLIC DISPLAY**

Sometimes system performance data is displayed publicly. When building owners wish to advertise the fact that they generate solar power for use on site, a display showing real-time energy output is an effective and interesting way to capture public attention. Such displays are not meant to be used in a technical way but rather to present data in an attractive and easy-to-understand format.



## REMOTE MONITORING DATA ANALYSIS

The value of a remote performance monitoring system is in the data it provides to system stakeholders. Once data has been collected, transmitted, and distributed, it can be analyzed, reported, and used for decision-making. Remote monitoring data helps system technicians, designers, administrators, and financiers ensure the sustainability and replicability of energy system installations.

### CORRECTIVE AND PREVENTATIVE MAINTENANCE

Perhaps the most valuable advantage of remote performance monitoring is the ability to anticipate or identify faults or problems in a system's functioning without frequent field visits by technicians. Site inspections by trained technicians can be costly and time consuming, especially for remote installations. If problems occur between scheduled visits or if the technician requires additional tools or parts to service the system, prolonged energy system outages can occur. By alerting technicians to system failures or problems as or before they occur, and by allowing them to diagnose the problem in advance, remote monitoring systems can significantly reduce or eliminate downtime.

### SYSTEM DESIGN

Beyond faults or problems with system operations, remote monitoring data can also help reveal flaws in system design. Such problems may not arise from malfunctioning equipment or insufficient maintenance but from the system's basic design. Such problems could affect the efficiency or sustainability of the system; for example, a battery bank may be undersized for facility loads, leading to premature battery failure. Remote monitoring data helps designers and technicians identify design flaws to refine future installations or correct existing installations.

### PERFORMANCE REPORTING

Remote performance monitoring can also give peace of mind to managers at the institutions concerned with financing or administering energy system installations. Energy systems are expensive to buy and install, and power equipment typically has a long lifespan (more than 10 years); therefore, ensuring system longevity is important. Remote monitoring data not only enhances system sustainability, through timely corrective maintenance, but also assures managers and financiers that their resources are being used effectively. Long-term data on energy system performance helps administrators replicate successful installations and encourages additional investment in health facility energy infrastructure.