

Using a Mobile Demonstration Cart to Introduce Solar PV System to College Students

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Introduction

Tribal communities in rural Arizona face energy challenges such as a lack of access to electricity due to rural locations, grid expansion, and permitting issues (Chee, 2013). According to the Navajo Tribal Utility Authority (NTUA), approximately 15,000 homes on the Navajo reservation lack electricity (Singer, 2020). In August 2020, the Navajo Nation and the Navajo Nation Council authorized the Navajo Tribal Utility Authority (NTUA) to buy and install off-grid 3.0 KW residential solar units (Navajo Tribal Utility Authority, 2022). Off-grid systems include energy storage capabilities providing complete independence from utility-supplied electricity. The STAR School in Leupp, AZ (recognized as the first off-grid charter school in the nation) (Sorenson, 2019) is an example of an educational institution in a rural area adapting to off-grid energy production. The K-8 program has an enrollment of 115 students serving primarily a Navajo population. Energy is provided by multiple solar PV arrays, an extensive battery-bank energy storage system topped off with wind turbine systems (M. Sorenson, personal communication, September 13, 2019). A barrier to achieve renewable energy development is the shortage of qualified human resources (Lucas, Pinnington, & Cabeza, 2018).

The off-grid solar market comes in different forms, ranging from ‘pico-solar’ products such as solar lanterns, to solar home systems, agricultural and commercial applications, and solar-powered mini-grids (Gaventa, 2021). Unfortunately, available access to tour such systems for university laboratory instruction is limiting due to geographic distance.

We searched for a method to best instruct our students on solar photovoltaic (PV) systems, with a focus of off-grid solar PV systems. During an online search of solar demonstration systems, we found a link to a video of *Renewable Energy: Solar System Components* (Jenkins, 2012) posted to YouTube video platform. Our goal was to create a mobile station to demonstrate the operation of individual system components operating in a residential grid-connect and/or stand-alone PV system when solar modules are exposed to sunlight, and under conditions of poor sunlight. Demonstrating the use of stored energy (i.e., batteries) to generate power for both alternating current (AC) loads and direct current (DC) loads, such as lights, fans, and pumps for moving water is an objective of this project.

How it Works

We viewed the video several times and reached out to the creator, Dr. Thomas Jenkins at New Mexico State University (NMSU) via email expressing interest in replicating his project for instruction at our university. From the video, we documented all the components featured and developed a cost-list. We secured funding from an institutional grant source in 2019 and purchased all the materials. Work began on constructing a board and mounting and wiring it to the mobile cart in fall 2019. Steel pipe was cut and welded to the back of the mobile cart. Plywood was cut, stained, and mounted to the support pipe. A sketch of the layout of components and a wiring diagram was created. We tested the operation of the system. One modification made was to create a set of longer solar PV cables and to physically place the two

solar modules outside our laboratory facility toward direct sunlight. The battery bank was charged to energize the demonstration system. The operating system was demonstrated to students enrolled in our Solar PV Energy Sources lab course in spring 2020. Our most recent use of the system was with our spring 2022 course.

Implications

The operating system provides our students with access to a working demonstration off-grid solar PV system. Students are tested on knowledge and understanding of use and function of individual system components. Instruction on both Alternating Current (AC) and Direct Current (DC) electrical systems, and comparisons made to PV-Direct systems, Stand-Alone (DC) systems, and Grid Connect systems. Students use a digital multimeter to measure voltage, amperage, resistance, and calculate electrical power. The system provides an opportunity to instruct in the use and interpretation of electrical wiring diagrams. Student achievement on assessments focusing on stand-alone solar PV systems was higher than on similar assessments without the stand-alone demonstration system.

Advice to Others

To introduce students to solar PV energy systems, consider the different types of systems. Start with simplest (PV-Direct) examples such as a solar-powered water fountain or DC fan. A stand-alone solar PV system consists of solar modules, charger controller, solar batteries, and DC load. A complete off-grid solar PV system includes both AC and DC electricity systems. For pre-service teacher education students, be sure to address science and math standards related to solar PV systems.

Solar PV modules can be wired in either series (positive to negative) to increase the voltage to accommodate a 24-volt system or wired in parallel for higher amperage to charge two 12-volt batteries. With a 120VAC outlet, electrical devices such as fans, phone chargers, radios, and popcorn machines can be plugged in to demonstrate how the system works for providing Alternating Current (AC) to typical household appliances. Design your system to fit your facility needs so you are able to move your system outdoors on a level surface. Interested users are encouraged to click on the link in the reference section of this abstract to access and view the video presentation of the system presented by Dr. Thomas Jenkins, NMSU.

Resources Needed

The complete mobile demonstration system was constructed for \$4,050.00. Components include 100-Watt Solar PV modules (2), PWM charge controller, 1500Watt inverter, safety disconnect switch, battery switch (2), 12V AGM solar batteries (2), DC light, battery monitor, AC panel with two 15A circuit breakers, 15-amp residential duplex receptacle, AC light, steel lab cart, pipe, 10 AWG PV cable, insulated conductor, plywood, and mounting fasteners. Research the costs of materials. Majority of items were available from online vendors (Amazon.com, Ebay.com., Blue Seas) and local do it yourself centers. A recommended reference source for the Do It Yourselfer (DIY) is the *Home Power Magazine* (Munro, 2010; Woofenden, 2012).

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