Sustainability in Practice with the Reflective Solar Tracker

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Abstract

RST installations at the (right) University of Scranton and (left) Pennsylvania State University

The Reflective Solar Tracker (RST)* is a solar collection device utilizing both reflected sunlight and a rotating base platform to increase the energy density impinging on commercially available solar panels. The extra sunlight from reflection saturates the individual crystalline solar cells while the rotating base ensures the saturation takes place for a longer portion of the day compared to conventional stationary installations. The repositioning of the base platform is accomplished using a gear and worm screw turned by a low power direct current motor under the control of a Raspberry Pi† computer. The Raspberry Pi computer calculates motor-on time intervals using solar astronomical data, collects and stores voltage and current data automatically into a daily data file, calculates the instantaneous power output, and finally sums the total energy output at the end of the day. Tracking the sun and increasing the incident sunlight allows for a longer solar day, meaning the maximum power output of the solar panel is sustained for a longer period of time. The initial study shows the RST outputs 140% more electrical energy on perfectly sunny days than its conventional counterpart.

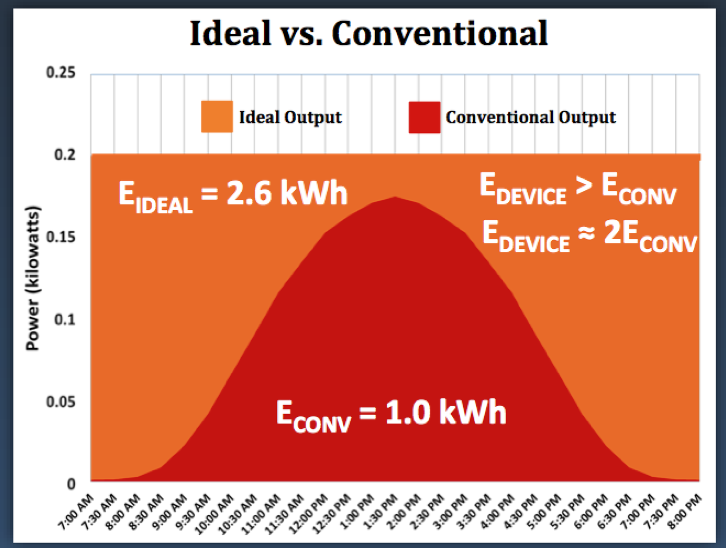
Project Education

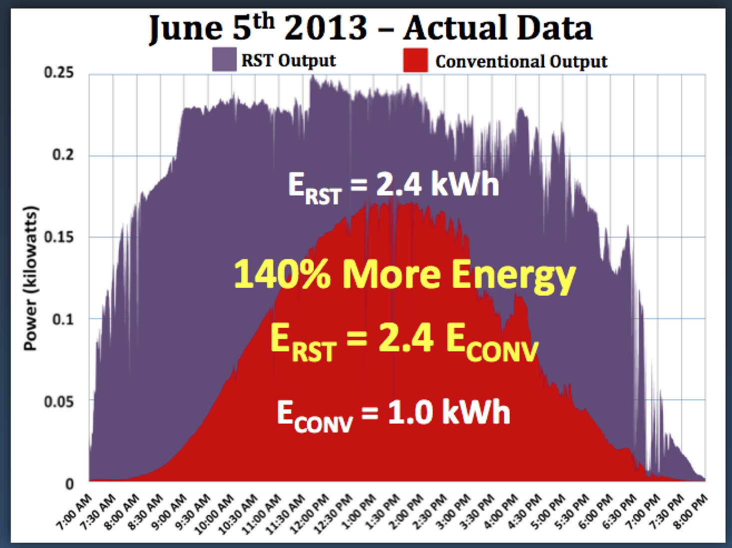
This device serves as a conduit to teach students the physics of sustainability. The project includes six faculty student research projects and counting leading to multiple poster and oral presentations at several conferences. In addition, two mobile RST devices were installed at locations in Uganda. One device is being used at St. Joseph's secondary school where the students are collecting data and sending it back to the University of Scranton. The second parish location is using the RST to power a few classrooms and a solar water pump sent along with the device. Not only is this device an excellent physics and engineering teaching tool, it is also teaching students about social justice. Our young physicists and engineers are being transformed into concerned scientists capable of viewing the world through more than just a technical perspective.

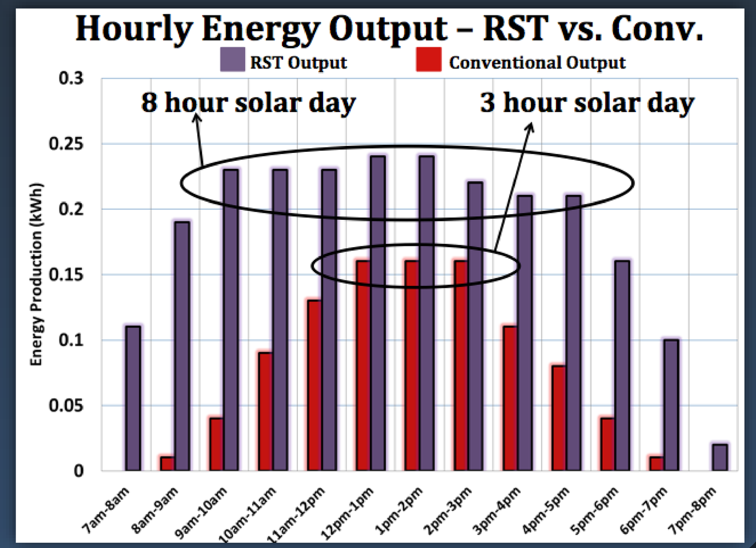
RST Physics and Results

A common solar panel misconception is that they produce maximum power continuously while the sun is out. If this were true, then the ideal energy output for a 200-watt panel would be represented by the orange area in the first plot below. In reality, the sun rises and progressively moves across the sky at most latitudes until it sets. This causes the sunlight to become incident upon the solar panel at changing angles when the sun is at different altitudes above the horizon (Tarbuck 2012). The actual 200-Watt solar panel energy output looks more like the red area labeled as the conventional output. The red area shows increasing power in the morning and then decreasing power in the afternoon in response to the sun's altitude angle.

After the RST was constructed and tested, the latter two plots below were created with data collected from the RST on June 5th, 2013. This data shows that with the combination of reflection and tracking on a perfectly sunny day, the RST outputs 140% more energy than a conventional installation, greatly increasing it's solar day.





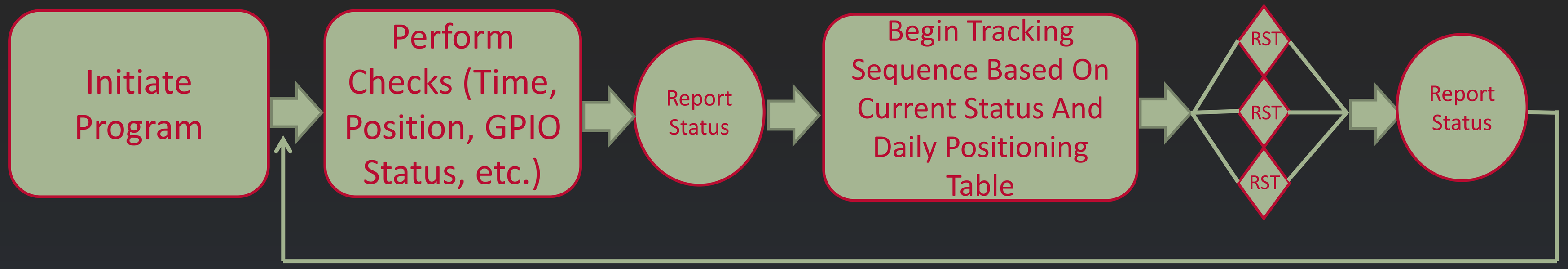


Collaboration and Motivation

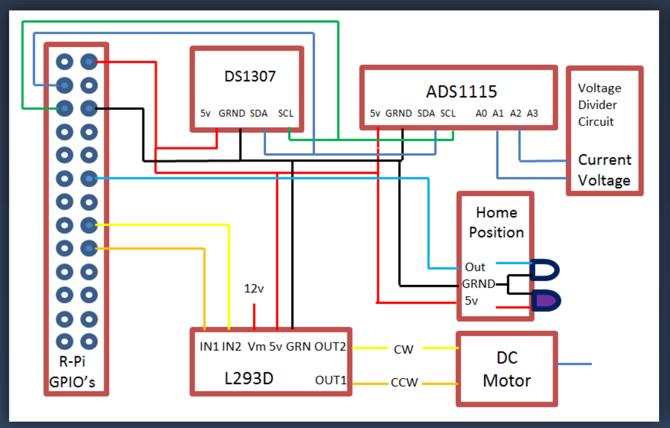
The motivations and goals of this collaboration are simple. First, nearly three and a half trillion kWh of electrical energy is consumed every year in the United States. This number is growing and cannot be sustained for every generation to come (EIA 2013). There needs to exist new means of producing more electrical energy while still being sustainable in the process. Second, energy is a precious resource. Inspiring others to investigate and experiment with new sustainable energy producing devices was a goal of the collaboration from the beginning. Third, the human condition depends on energy as much as anything else. The human condition of most Americans is comfortable when compared to conditions around the world. There needs to be a means of sustaining our lifestyle for generations to come while also improving the human condition for those without the resources to improve it themselves.

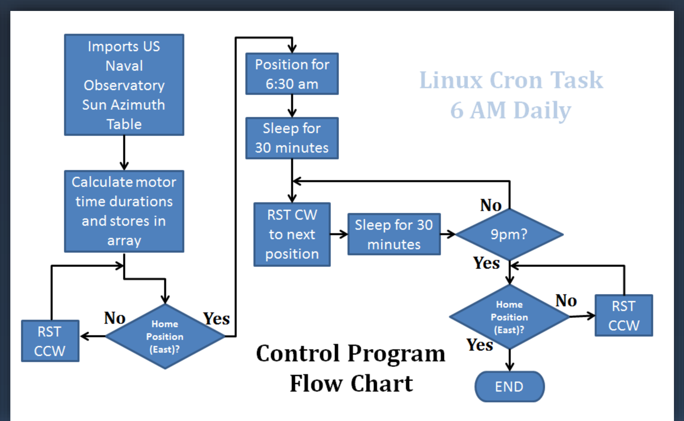
Funding for this collaboration was made possible by The University of Scranton and the Sustainable Energy Fund (SEF). The SEF logo is the silhouette image of an adult looking down on a child whom the adult is embracing. This image of unconditional support for a child is meant to convey the concept of intergenerational responsibility. There is, however, no evidence in the logo defining the relationship between the adult and the child. This is done on purpose to express the desire to extend not only your family's well-being but the well-being of everyone on the planet we share.

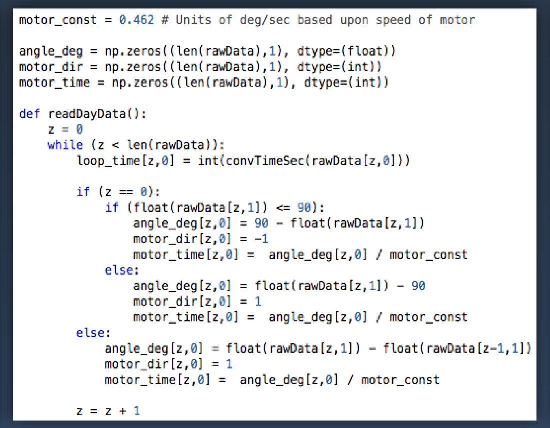
How Does it Track?

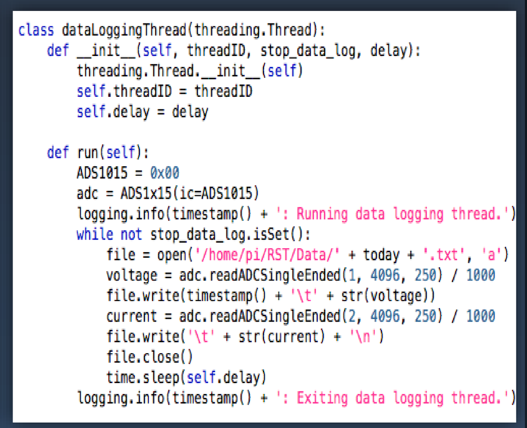


The beauty of using the Raspberry Pi as the brain behind the RST is its ability to control external devices and monitor as well as report data through the use of its GPIO pins. The GPIO pins make the Pi a viable microcontroller for the RST. Using one of the Pi's supported programming language, Python, a program was created to complete the required daily tasks. The program controls an electric motor rotating the RST base platform through the use of look-up tables from the United States Naval Observatory while simultaneously calling sub-processes performing "self-checks" to ensure the RST is on-track. To perform the sun "tracking", the program uses an external clocking device and a timing algorithm that will correctly position the RST to face the sun. At set intervals, the program calls forward additional functions to record voltage and current data to calculate the power output with the use of an analog to digital converter using I2C (Inter-Integrated Communication) and report data through the use of a Wi-Fi/Bluetooth adapter.



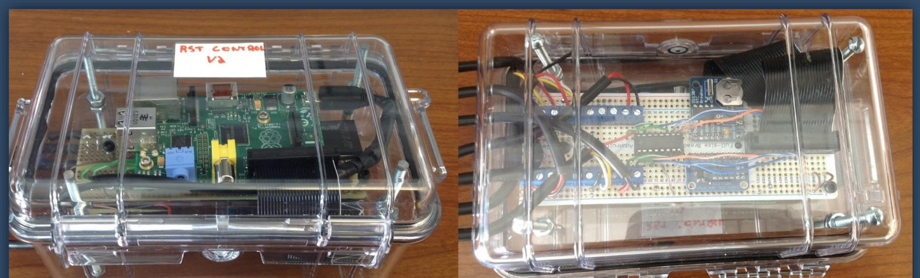






Celestial Body Digital Tracking System

Building off of the concept described above, the Celestial Body Digital Tracking System was developed using the Raspberry Pi computer as its control board. This system utilizes simple components interfaced together to create an output capable of powering a motor allowing the RST to follow the sun. Starting from left to right, the pictures above demonstrate this system. The first picture shows the block schematic and how the components are interfaced together. Next is a flow chart of how the RST program is executed. Lastly are two samples of the code used to pull data from the U.S. Naval Observatory and convert it to motor-on intervals, and of how the program collects and stores data. Shown to the right are pictures of the latest system that was sent to Uganda, Africa along with an RST to a secondary school. This system is fully functional as a RST microcontroller but has some additional features that make it simpler to connect to any device, and better serves as an educational tool.



Project Outcomes

We once said if the RST could simply light the darkness in just one schoolhouse somewhere in the world, our goal of beginning to improve the human condition would be fulfilled. In December of 2013, the collaboration was given this opportunity. We were able to send two RSTs to two locations within Uganda, Africa with students from The University of Scranton. One of these RSTs will serve as a charging station for battery powered devices during the day, and light a school classrooms at night. Accompanying the RST was a modified Celestial Body Digital Tracking System that will be used as an educational tool for the school. The second RST was sent to a rural location and will be used to power a water well pump. Before having this pump, the people who lived there had to hand-pump the water, which took hours of their time in the morning. The RST will save them many hours that can be used for other tasks. The photo taken below is of the students who participated in this endeavor, assembling the RSTs near the schoolhouse in Uganda. The RST is most likely not the answer to all of our planet's energy problems. This does not mean, however, the impacts from this project were not literally felt on the other side of the world. We made a difference for these people and that is what really matters. Something we will all remember forever.

Students installing an RST in Uganda

References

*Patent Pending Devices †Raspberry Pi is a trademark of the Raspberry Pi Foundation

Tarbuck, Edward J. et all. (2012). *Earth Science*. 13th Edition. pg. 468. United States: Pearson Education

Energy Information Administration (EIA), Electric Power Monthly with Data for October 2013, December 2013

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