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Research Experience for Secondary School Teachers on Renewable Energy: Design and Implementation of a Small Scale Solar Tracker

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Research Experience for Secondary School Teachers on Renewable Energy: Design and Implementation of a Small Scale Solar Tracker

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Abstract

This paper describes the experiences gained during the first year implementation of a Research Experiences for Teachers (RET) in Renewable Energy (ENERGY) at Georgia Southern University (GSU). RET is a NSF grant program that supports the professional development for secondary school teachers with emphasis on hands-on laboratory research and experiences in STEM fields. The paper also refers to the teachers' experiences gained at the GSU Engineering Research Labs during the summer 2017. Participants in the RET program completed 280 hours (seven weeks) of training and research experience in renewable energy topics. About 50 hours were devoted to lectures and workshops, and the rest, about 230 hours, were research activities, collaborating in research teams with undergraduate and graduate students, and engineering professors. Participants also developed lessons for their courses that were delivered to their own students during the 2017-2018 school year. The lessons were directly related to the experiences that teachers gained in the summer.

Keywords

Research experience for teachers, solar tracker, renewable energy

Introduction

This paper describes the experiences gained during the first year of implementing an NSF Research Experiences for Teachers in Renewable Energy at Georgia Southern University. The RET-ENERGY program at GSU is an intensive summer program of seven weeks where secondary school teachers complete 280 hours of training and research experience in topics related to renewable energy.

The training portion of the program (50 hours) includes workshops on renewable energy topics as well as on education topics. The workshops on renewable energy were delivered by faculty from the College of Engineering and Computing, and the education topics were delivered by faculty from the College of Education. RET participants devoted the rest of the time, about 230 hours, in research activities, working together with undergraduate and graduate engineering students in the engineering research laboratories.

It is important to emphasize that the RET-ENERGY recruitment channels are mainly focused in attracting highly capable teachers that work on high-need rural areas that are home to high populations of underrepresented minorities and in economic disadvantage. The next sections describe in detail the organization and research activities that were performed by the teachers during the summer 2017.

RET-ENERGY Set-up

During the summer 2017, nine secondary school teachers participated in the RET-ENERGY program. The summer activities were divided in: a) workshops, b) visits to industries, and c) research experience.

The workshop topics included: laboratory safety and health effects of emissions, wind energy, solar energy and photovoltaics, solar panels, pico-grid, exhaust heat, heat transfer, bio-flow networks, and STEM education and assessment. The workshop activities took place during the first two weeks of the summer, and all nine participants attended all the workshops.

The visits to industries were scheduled one every Friday, and the industries that were visited included Honda, Briggs & Stratton, JCB, Herty Advanced Materials Lab, and the National Peanut Research lab.

For the research experience, the participants were divided in teams of two, and each team was placed in a research lab in accordance to their interests in renewable energy topics. The research topics that were available for the RET participants included Thermoelectric Power generation, Wind Energy generation, From Smart Grid to Smart Home, and Solar Tracker systems.

In particular this paper is focused on the experienced gained by two of the RET participants that were involved in the Solar Tracker research module. Therefore, the following sections explain in detail the activities performed by the teachers in this research module.

Solar Tracking System

Finding energy sources to satisfy the world's growing demand is one of society's foremost challenges for this century[1]. Converting sunlight to electricity via photovoltaic (PV) solar cells can dramatically reduce the cost of electricity. In this context sun trackers are very important devices for efficiency improvement [2]. The main objective of this module was to design and implement a dual axis tracking solar system that was efficient and cost effective. SolidWorks was used to design the mechanical parts that included the base and frame to house all the electronic components of the system. The electronic components of the system consisted of two motors (a servomotor and a stepper motor), a 10 watts solar panel, an Arduino microcontroller, a Ni-Cd battery, and sensors (temperature, humidity, light intensity, compass, and GPS). The two motors are used to move the solar panel on the vertical and horizontal axis, depending on the azimuth and latitude, to allow for optimum energy to be captured by the solar panel. A Ni-Cd 12V battery was used to store the energy captured by the solar panel. An Arduino microcontroller was used to collect information from the sensors, and to control the motor movements. A micro-SD card reader was used to store the weather data such as temperature, humidity, light intensity, time, and the voltage generated by the solar panel. Analysis of data showed that the temperature and the power produced by the solar panel were directly proportional, and the system was able to track the position of the sun with an accuracy of +/- 1^{o} (degree). Figure 1 shows the SolidWorks design of the solar tracking system, and figure 2 shows the actual solar tracking system.

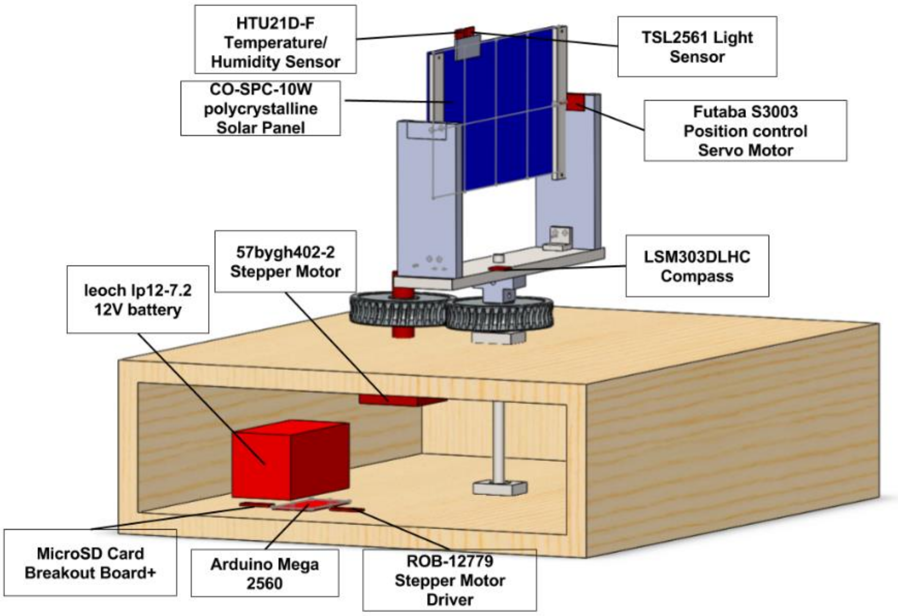

Figure 1: SolidWorks design of the Solar Tracking System

Figure 2: The Solar Tracking System

Operation of the Solar Tracking System

The prototyping tracker system operates in the most common two-axis controlled tracking system, that controls the azimuth and latitude, using a controller to position the solar panel surface to face the sun's rays always perpendicular. The controller uses a global position system (GPS) module to read the actual position of the solar panel. To correct the position, the controller calculates the correct azimuth and latitude of the sun's rays by solving a sun tracking equation[3,4]. This equation uses initial given information, such as local time, date, geographical location, and time zone. Then the control program in the Arduino microcontroller generates digital pulses that are sent to the motors (servo and stepper motor) to relocate the solar panel to point directly to the sun's position. Figure 3 shows the flow chart of the tracking system. Figure 4 illustrate the main hardware components that were used in the implementation of the tracking system.

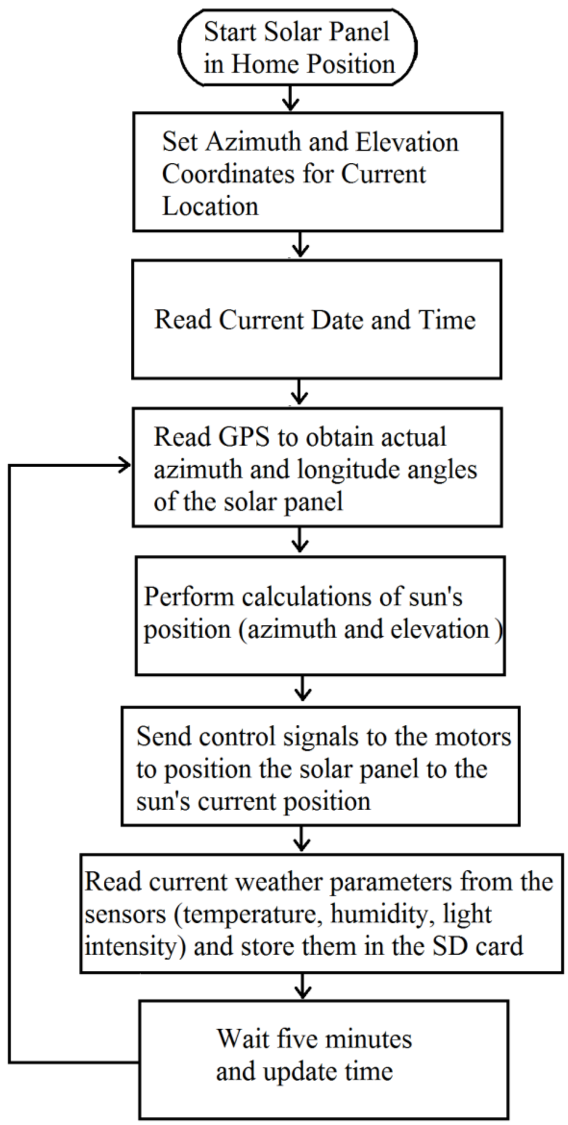

Figure 3: Flow Chart of the Tracking Control System

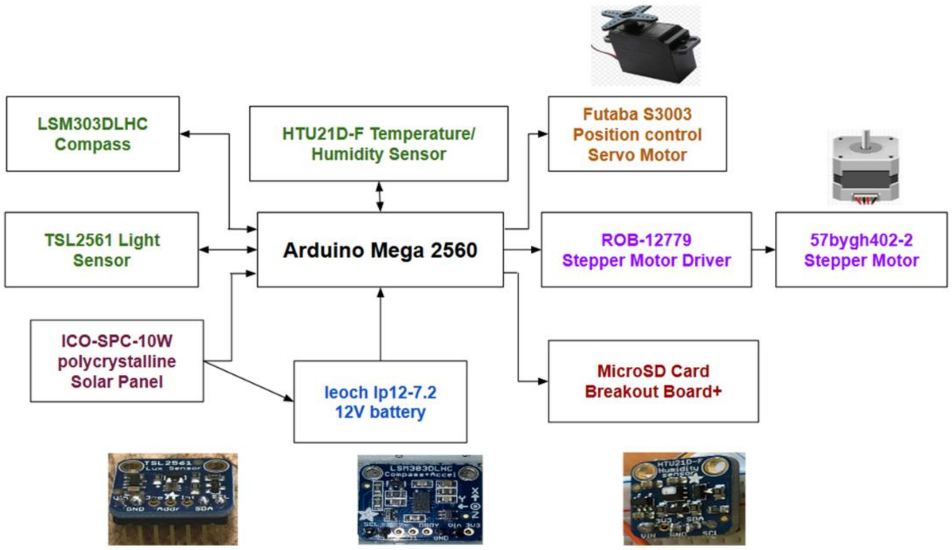

Figure 4: Main Components of the Solar Tracking System

Experimental Setup and results

A suitable geographical location, without blocking of any buildings or plants, was selected to test the performance of the system. Data was collected on July 19, 2017, from 12:30-4:30pm ET at the coordinates: latitude: 32.4232^{o}, longitude: – 81.7864^{o}. The temperature fluctuated between 31^{o}C and 49 ^{o} C, the voltage generated by the solar panel was between 11.2 and 12.2 volts. The solar panel was able to track the position of the sun with an accuracy of +/- 1 degree. It was observed that the temperature and power produced by the solar panel were directly proportional.

Transfer Experience to Classroom.

As part of the RET-ENERGY program, the secondary education teachers developed a module to transfer processes, concepts and knowledge acquired during the summer program, to their own secondary institutions. In particular teachers working in the solar tracking system developed a module on engineering authentic instruction for their own classrooms. Table 1 illustrates one of the modules that the participants developed as part of the RET-ENERGY experience.

Conclusions

RET participants were able to collaborate and work in research labs under supervision of a research faculty mentor, and in cooperation with a graduate and an undergraduate student. The research team developed a project designing and implementing a cost effective solar tracker system that was able to track the sun with an accuracy of +/- 1°(degree). Also, teachers worked in a project that fitted their school’s interests and capabilities. Furthermore, the workshops on the education module, prepared the teachers in topics such as research methods, technical writing, authentic teaching practices including problem-based and place-based learning methods for teaching 21st century reasoning through an energy context. Combining the knowledge acquired in the education modules, and the research experience in the solar tracker project, teachers designed lectures and assessment materials that were transferred to their own institution, creating modules as the one shown in Table 1. Moreover, teachers were exposed to a diverse set of renewable energy topics, and learned to use several instruments and software necessary to accomplish their project tasks. In particular teachers learned how to use digital multimeters, oscilloscopes, and became familiar with the Arduino C language. They also were exposed, and became familiar with different types of sensors that are used with the Arduino microcontroller. These sensors were used to measure temperature, humidity, light intensity, and global position coordinates.

Table 1: Engineering Authentic Instruction Module

Title of Unit:	Latitude, angle of Sun, and Solar Energy	Grade Level	8^{th} grade
Curriculum Area:	Physical Science	Time Frame	3 days
Developed by:	Tricia Kirkland		
Identify Desired Results			
Understanding		**Essential Questions**	
Students will understand that ..		**Questions that provoke, address conceptual foundation**	
• As the angle of the sunlight striking Earth increases, the surface area hit by sun beam on Earth will decrease. The same is true for light energy: decrease. • The angle of the sun's rays can impact temperature. • The sun's rays hit more directly at the equator and indirectly at the poles. • The tilt of the earth's axis causes the sun's rays to be more direct in the winter that in the summer. • Fossil fuels are nonrenewable and finite resources that are being used at an extremely fast rate. • Alternative energy resources must be utilized and further improved upon in order for citizens of earth to have electricity and transportation. • Alternative energy needs to be utilized to protect our environment from harmful emissions. • The sun provides radiant energy that can be transformed into mechanical, electrical, and thermal energy.		• How can the sun's energy be used as a renewable resource? • What is the relationship between the angle of sunlight hitting Earth and the surface area lit? • What is the relationship between the angle of sunlight hitting Earth and light energy?	

Acknowledgments

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Biographical Information

Rocio Alba-Flores

Rocio Alba-Flores received a BS in Electrical Engineering from the National Polytechnic Institute, Mexico. She worked for Fairchild Semiconductors, Mexico, as a Technical Marketing Engineer. She obtained her MS and Ph.D in EE degrees from Tulane University. Previous academic experience includes Visiting Professor at Trinity College, Hartford, CT, and Assistant Professor in the Electrical and Computer Engineering department at the University of Minnesota Duluth. Currently she is an Associate Professor in the Electrical and Computer Engineering department at Georgia Southern University. Her main research interests include robotics, control, image processing, remote sensing, digital systems, and microprocessor applications.

Tricia Kirkland

Tricia Kirkland is a science teacher with a certification in middle and secondary science education. Her educational background includes an undergraduate degree in Chemistry, M.Ed. Secondary Science Education, and an Ed.S. Teaching & Learning, all from Georgia Southern University. She has professional skills in working with laboratory equipment/instruments in the industrial setting, data analysis, and regulatory affairs. Also, she is a co-author (Tricia Hughes) of an article entitled "Teacher Perceptions of Interactive Whiteboards: A Comparison of Users and Future-Users in High School and Middle School Mathematics" published in the Association for the Advancement of Computing in Education (AACE).

Lindsay Snowden

Lindsay Snowden graduated from Georgia Southern University with a Bachleors of Science degree in Biology in 2016. She continued her education at Georgia Southern in the

Masters in the Art of Teaching Program in secondary education and she will be graduating in May of 2018. In the summer of 2017 she completed the NSF RET-ENERGY program and had an amazing learning experience due to both the professors, graduate assistants, and fellow researchers. Currently, she is teaching 7th grade Life Science at Bryan County Middle School in south east Georgia and enjoying her time as a new teacher.

Deon Lucien

Deon Lucien is a graduate student in the Master of Science Program in Electrical Engineering at Georgia Southern University. He received his BS Degree in Electrical Engineering from Georgia Southern University in the spring 2017. His areas of interest include the design of antennas, wireless communications, and robotics.

Dallas Herrin

Dallas Herrin is an undergraduate student in Electrical Engineering at Georgia Southern University. His areas of interest include microcontrollers, solar energy, and robotics.