

Green Fund Project Final Report

This report may be published on the SIU Sustainability website.

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Faculty Advisor (if applicable):

Project Title: **Clean Electric Energy from Hybrid Renewable Energy System –Phase I: Proof of Concept**

Project ID #: **19SP105**

Award Date: **04/30/2019**

Project Completion Date: **01/31/2020** (*Report Submission Date: 02/28/2020*)

Total Funds Used: **\$3,000**

1. Provide a summary of your project/project experience.

In this project, a “hybrid wind-solar power system” was experimentally implemented in Power Systems Design Lab located in the Department of Electrical and Computer Engineering. The successful development of this project helped us achieve a systematic and efficient framework to harness the clean energy from wind speed and solar radiation. At this point, only 0.17% of the campus electric load is supplied by clean energy (i.e., by the PV array next to the SIU Tennis Courts). The robust lab-scale hybrid system that we achieved in this one-year project can be used as an *effective platform (i.e., Proof of Concept)* to implement a larger-scale wind-solar power system on our campus. Hence, our reliance on fossil fuels to generate electricity will be mitigated and we can move towards *cleaner energy production*. Figures 1 and 2 show the components of the system which are either purchased by the SIU Green Fund or the Matching Fund (i.e., the start-up package of the PI). Figure 1 presents the sources including the wind speed source (i.e., Fan), two wind turbines (horizontal axis wind turbine and vertical axis wind turbine), source of solar panels (i.e., LED lights) as well photovoltaic (PV) modules. Figure 2 illustrates the rest of the system (i.e., the wind circuit and the PV circuit). As can be seen, each circuit contains a *storage package* including battery and supercapacitor.

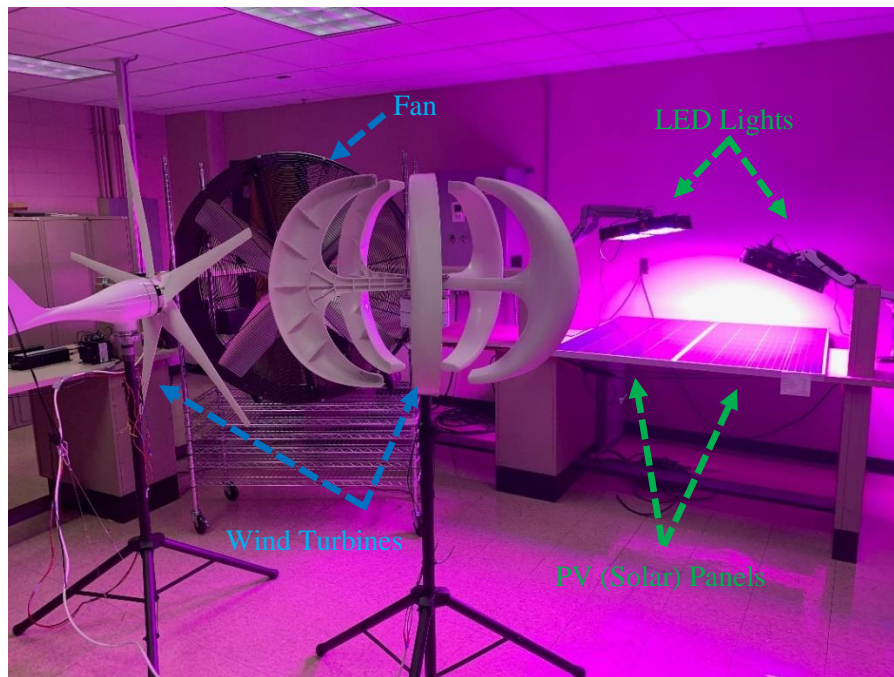


Figure 1: Sources of the hybrid system.

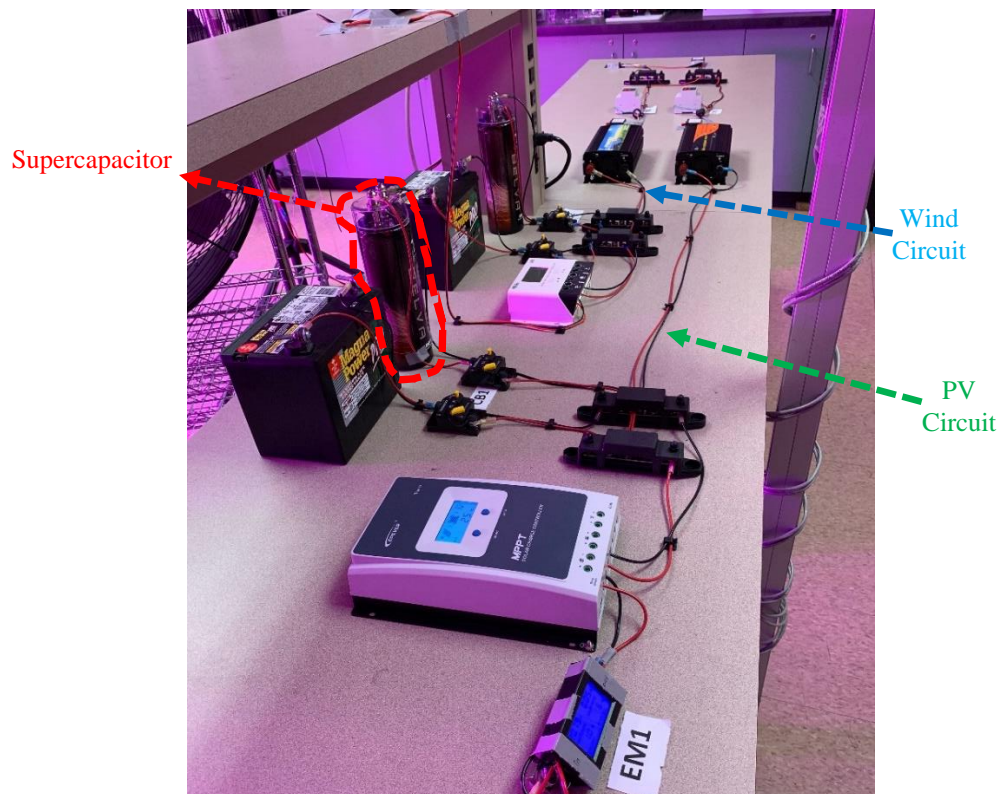


Figure 2: Rest of the hybrid system.

2. Provide a summary of your results (environmental, social, and/or economic) including quantifiable data as appropriate (ex. # of individuals reached, lbs. diverted from landfill, energy saved, etc.).

Here is the description of one of the tests implemented on the system. we turned on the four LED lights at $t=0$. Then, in order to examine a scenario in which solar radiation suddenly decreases, we turned off the two LED plant grow lights in **Group B**, shown in Figure 3 (a), at $t=28$ s and turned them on at $t=40$ s. In other words, we still have two lights from **28 s to 40 s** to represent a partially cloudy situation. Our storage system contains battery AND supercapacitor (refer to Figure 2). To precisely investigate the impact of supercapacitor, we implemented the described scenario for the following configurations:

- 1) PV modules with no storage (which is similar to the existing situation of SIUC PV array next to tennis court),
- 2) PV system upgraded with only battery, and
- 3) PV system upgraded with the implemented storage framework containing battery and supercapacitor.

As can be inferred from Figure 3 (b), generated current and power in the second and third configurations are almost the same **before $t=28$ s** when the steady fluctuations of PV's source are experienced through slight rotation of LED lights.

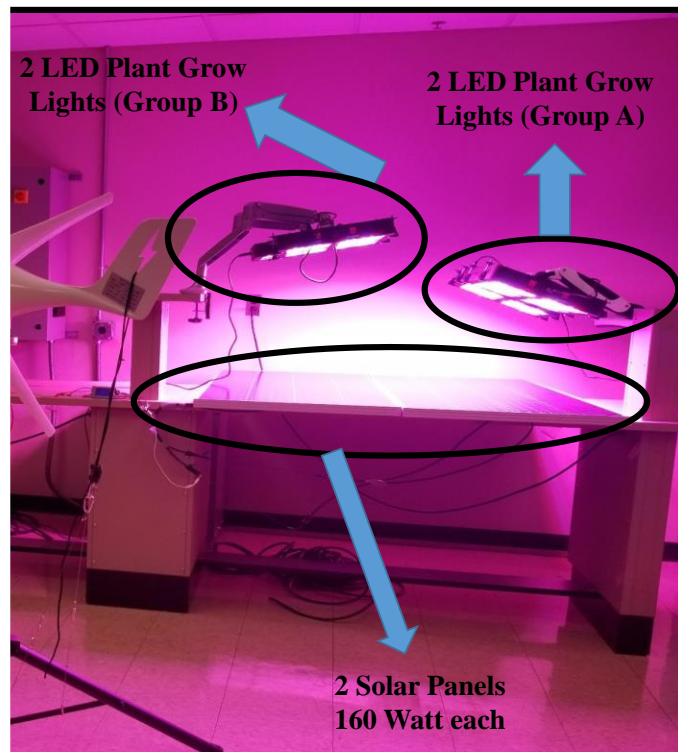
However, when two of the LEDs are turned off at $t=28$ s, a noticeable drop in PV's source occurs. In this period of the time (i.e., between 28 s and 40 s), the difference between generated current/power in the second and third configurations (i.e., blue solid curve and red dashed curve in Figure 3 (b)) is more noticeable.

More interestingly, **even after** turning on the lights of **Group B**, the generated current/power in the second configuration (i.e., red dashed curve in Figure 3 (b) representing battery only) requires a considerable time (i.e., from 40 s to 50 s) to become approximately the same with that of the third configuration (i.e., blue solid curve) containing both battery and supercapacitor.

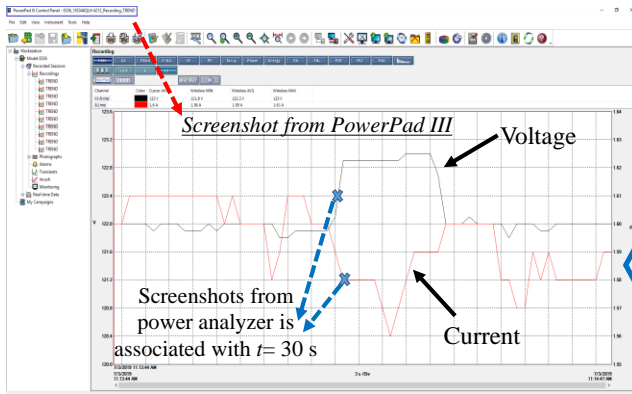
Different variables including Total Harmonic Distortion (THD), and End-to-End-Efficiency (ETEE) of HSSBS can be determined using the measurements by the power analyzer (see Figure 3 (c)) in order to validate that: 1) the power quality is acceptable (i.e., THD < 5%), 2) the peak currents injected to the battery are mitigated, and 3) the average energy saving in the developed framework (i.e., blue solid curve) is higher compared to battery-only configuration (i.e., red dashed curve).

One of the objectives of this project was to promote the application of supercapacitor in hybrid wind-solar systems as an effective strategy to cope with the uncertain nature of renewable energies (i.e., wind speed and solar radiation). As can be inferred from the results, the combination of battery and supercapacitor can effectively harness the renewable energy and reduce the stress applied on the battery. This is because battery has a higher energy density while supercapacitor has a higher power density. Therefore, the hybrid utilization of battery and supercapacitor in the implemented framework: 1) better captures the clean energy from wind turbines and solar panels and 2) improves the economy of the hybrid system.

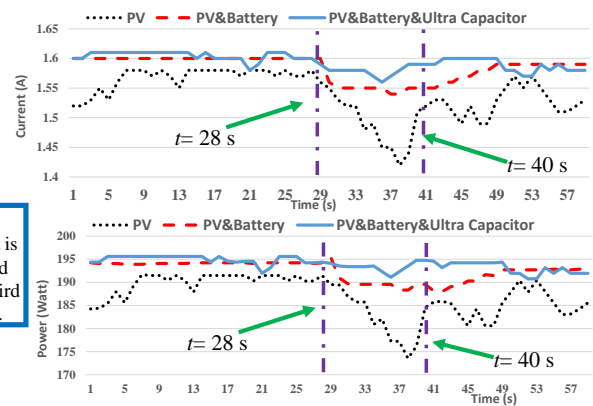
3 (a)



3 (b)



This screenshot is associated with the third scenario.



3 (c)



Figure 3: Experimental results at Power Systems Design Lab.

3. Summarize how your project promoted the Green Fee/Sustainability on campus including, but not limited to, flyers created, screenshots of website, signage, etc. Please include website links, if applicable. (Reminder: you are required to promote your project using at least 2 items from the awardee website promotion list.)
- a) As it can be seen in Figure 4, the Principal Investigator (PI) has updated the web page of Power Systems Design Lab (<https://engineering.siu.edu/elec/laboratories/research-labs/power-systems.php>) as follows:

"Dr. Asrari received the grant of \$6,000 from "SIU Green Fund" in 2019 to experimentally implement and validate a hybrid renewable energy system (HRES) in the Power Systems Design Lab. The title of the project was "Clean Electric Energy from Hybrid Renewable Energy System – Phase I: Proof of Concept".

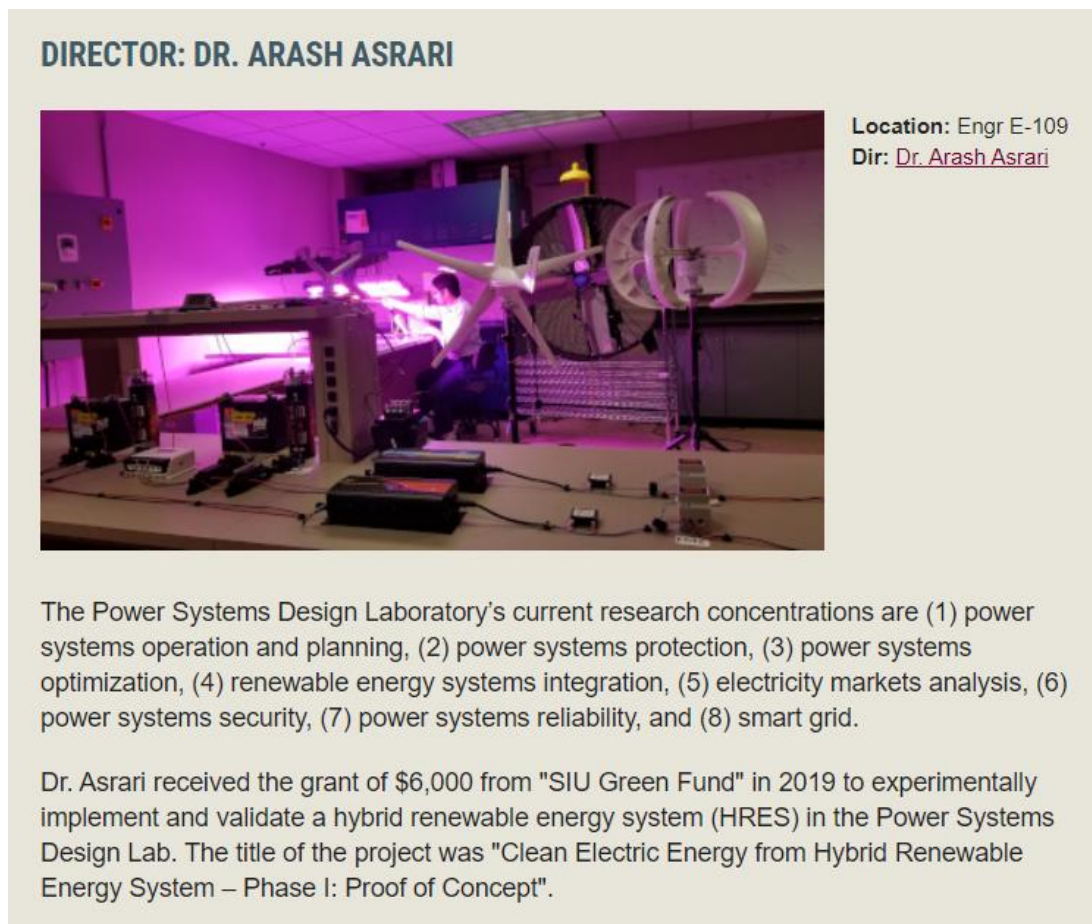


Figure 4: Webpage of Power Systems Design Lab.

- b) Mr. Bibek K C was a MS student working under the supervision of the PI and was a member of this project. In his MS Thesis Defense session, he mentioned that SIU Green Fund supported us to accomplish this project. The title of his MS Thesis was "Impact of a Hybrid Storage Framework Containing Battery and Supercapacitor on Uncertain Output of Wind and Solar Power Systems". In his thesis, he relied on the implemented hybrid system, funded by SIU Green Fund, to propose an effective method to store the generated energy of hybrid renewable systems. He successfully defended his Thesis and graduated in fall 2019. Moreover, in the last page of his journal paper (i.e., acknowledgement

section) which was extracted from this Thesis, he mentioned SIU Green Fund which supported this project. This journal paper is submitted to IEEE Transactions on Energy Conversion and is currently under review.

- c) The PI of the project hosted a workshop on SMASH day in summer 2019. Photos from this workshop can be seen in Figure 5. Launched in 2004 by Freeda Kapur Klein, SMASH is committed to “eliminating the barriers faced by **underrepresented people of color in science, technology, engineering and math (STEM)** and fostering their untapped talent for the advancement of our nation”. On 07/27/2019, The PI provided a voluntarily service to those students visiting SIU in SMASH program to show them the real-world impacts of clean electric energy resources on our environment. The workshop contained several hands-on experiments for the high school students to better understand the significance of Renewable Energy in electrical engineering. The students experimentally validated the outcomes of this project which was supported by SIU Green Fund.

Link:<https://www.smash.org/SMASH-STEM-Program-Launching-in-Illinois-in-Partnership-with-Illinois-Tech-SIU-Carbondale-and-CPASS-Foundation>



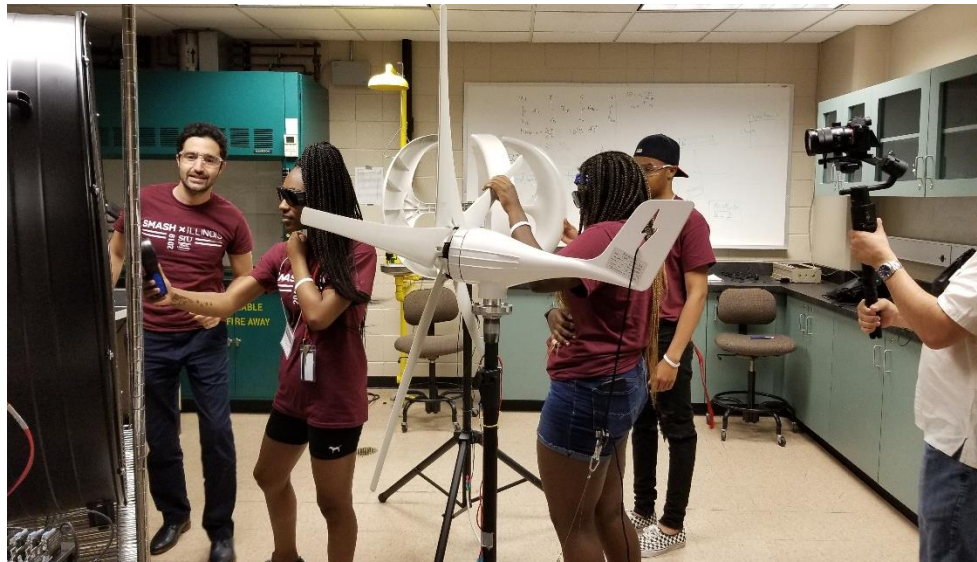


Figure 5: SMASH Day (07/27/2019) in Power Systems Design Lab.

- d) SIU Day is an event to welcome hundreds of high school students to campus and “help them discover what makes SIU Carbondale unique”. On 9/8/2019 (SIU DAY), the PI and his research team provided a voluntary service to those high school students visiting the ECE department. The outcomes of this project, supported by SIU Green Fund, were shown to those interested students in this workshop. Photos from this workshop are included in Figure 6.

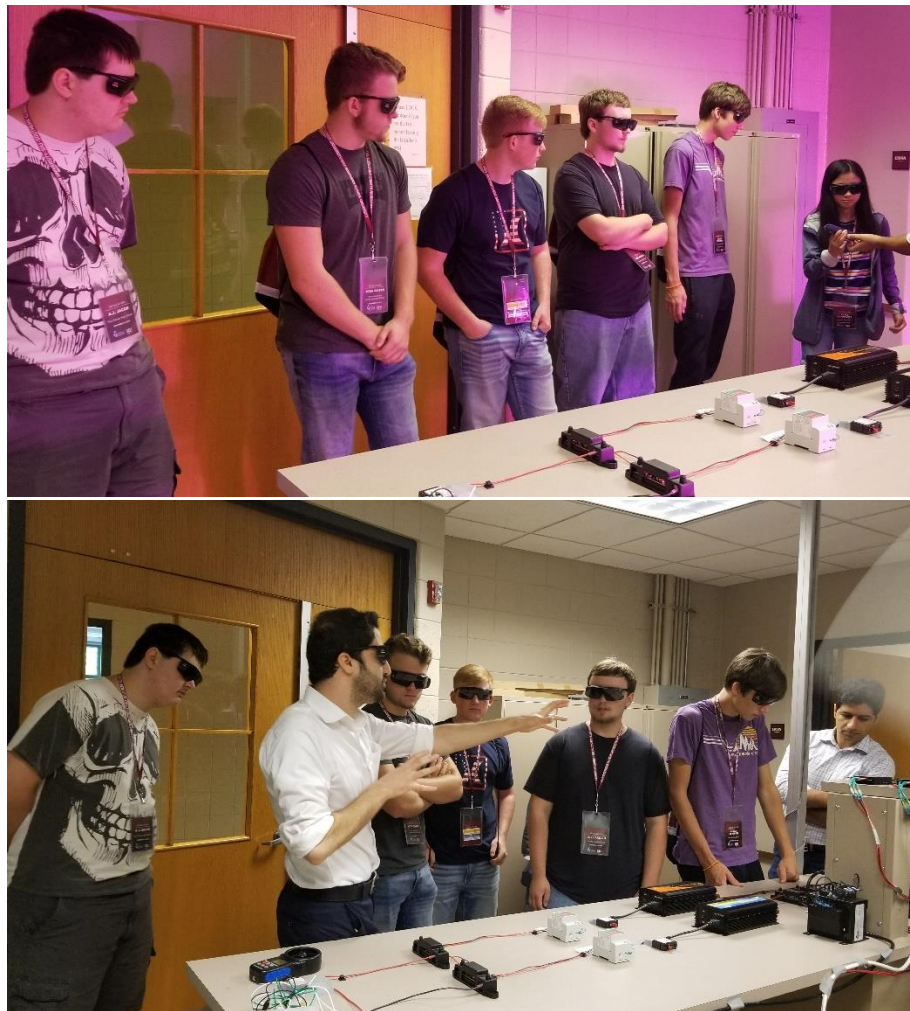


Figure 6: SIU Day (9/8/2019) in Power Systems Design Lab.

- e) Dr. Haibo Wang (<https://engineering.siu.edu/elec/faculty-staff/faculty/wang.php>) is a Professor in the ECE department of SIU and teaches different courses including **UNIV101-Section 063**. In order to provide an interdisciplinary presentation for those students who might be interested in Electrical Power Engineering, the PI (Dr. Asrari) presented the highlights of this project, funded by the SIU Green Fund, to the students of the course UNIV101-Section 063. The PI provided this presentation in fall 2019 per the request of the instructor of UNIV101 (i.e., Dr. Haibo Wang).
- f) The SIU Green Fund grant program recently worked on a short fund-raising video to bring attention to the program. The intent was to help “potential donors understand how the Green Fund supports the University’s mission and sustainability”. On 01/28/2020, The PI as well as the students involved in this project assisted the Director of Sustainability Office in preparation of this video in Power Systems Design lab. Figure 7 contains photos from this service. Link of Video: <https://siuday.siu.edu/giving-day/22291/department/25834>.



Figure 7: Fund-raising video (1/28/2020).

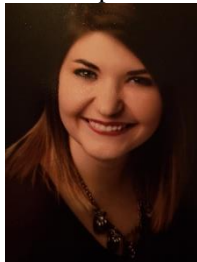
- g) In order to promote undergraduate students interdisciplinary research, one undergraduate student from the Department of Civil and Environmental Engineering (**CEE**) was added to our research team in the **ECE** department to work on this project. Her name is Haley Hostetter. The students involved in this project are included in Figure 8.



Meisam Ansari (**PhD** Candidate)
ECE Dept.



Samaneh Pazouki (**PhD** Student)
ECE Dept.



Haley Hostetter
(**Undergrad** Student)
CEE Dept.



Bibek K C
(**MS** Student) – Graduated
ECE Dept.

Figure 8: Students involved in this project.

4. Provide evidence of how you used the Green Fund Marker in your project.

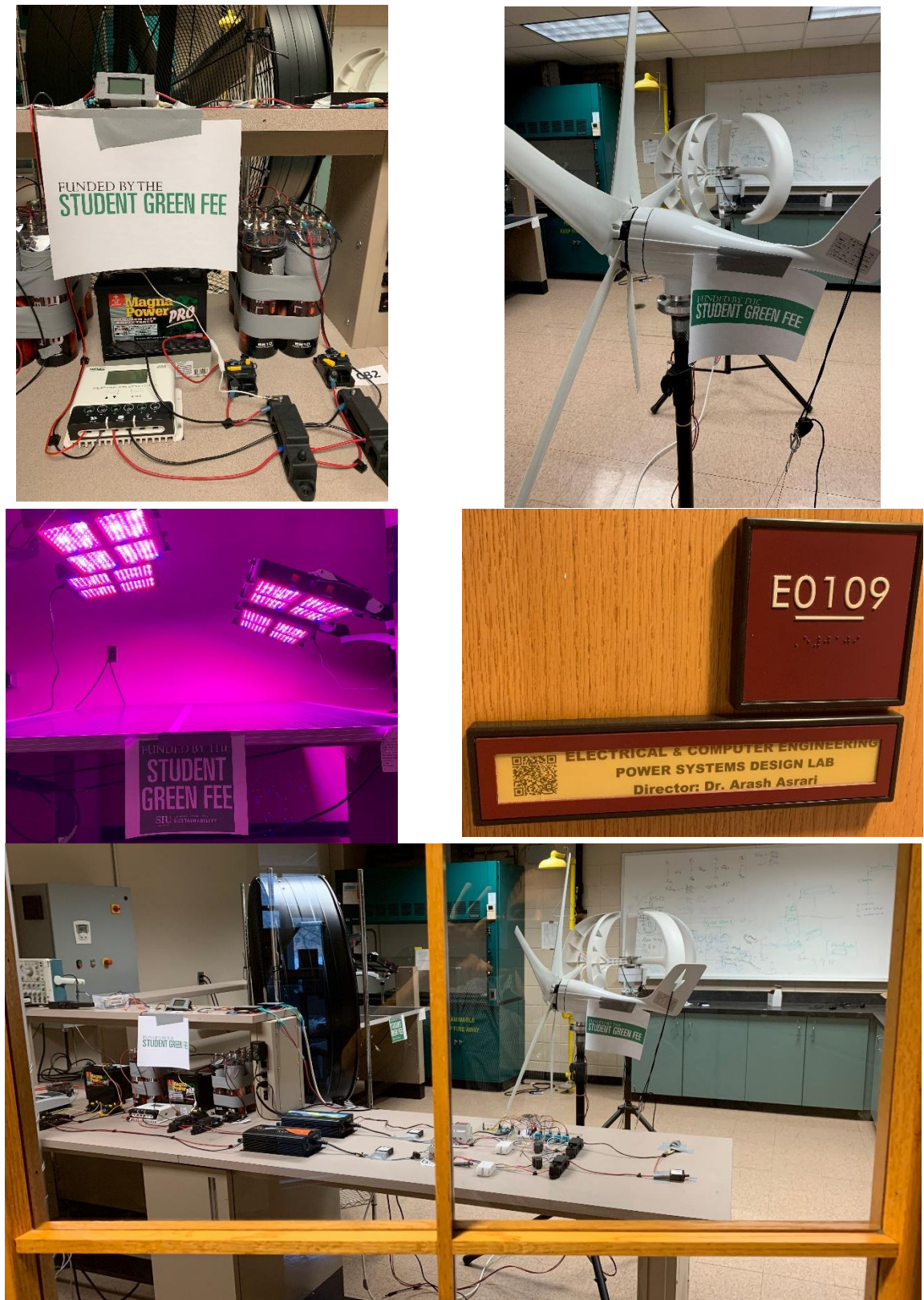


Figure 9: Green Fund Markers in Power Systems Design Lab.

5. Is there anything you would do differently if you were to do a similar project in the future? If so, please describe.

This project was more challenging for one of the students in my team who had not taken my course ECE 486: Clean Electric Energy. For similar projects in the future, I will encourage the entire members of my team to either take this course or attend the lecture sessions. This will provide them with a better background to improve their contribution in the project.

6. Provide as an attachment to the email (see email address below) a minimum of 5 digital images. A minimum of one of the five images should include a person. Images should be of high a quality as possible and be attached in jpg format, if available. Images will be used to promote interest in sustainability projects on campus and may be used on our website and in other promotional material. These can be photos of the progress of the project or the completed project. Provide captions for photos here.

Attachment 1: Figure 1: Sources of the hybrid system.

Attachment 2: Figure 2: The hybrid system.

Attachment 3: Figure 5: SMASH Day (07.27.2019) in Power Systems Design Lab.

Attachment 4: Figure 6: SIU Day (9.8.2019) in Power Systems Design Lab.

Attachment 5: Figure 7: Fund-raising video (1.28.2020).

Attachment 6: Figure 9: Green Fund Marker_1.

Attachment 7: Figure 9: Green Fund Marker_2.

Attachment 8: Figure 9: Green Fund Marker_3.

Attachment 9: Figure 9: Green Fund Marker_4.

Attachment 10: Sources and the circuit.

7. In 2-5 sentences, describe what you learned from completing the Green Fund grant process.

This project was a great opportunity for my research team (see Figure 8) to understand how the energy from wind speed and solar radiation can be harnessed to generate Clean Electric Energy. In addition, they learned how to experimentally evaluate the uncertainty of wind power and solar power. Moreover, they accomplished different tests to tackle the nondispatchable nature of renewable energy. Furthermore, they realized that how the hybrid utilization of battery and supercapacitor can better store the extra energy from wind turbines and solar panels (see Figure 3). Most importantly, my students had an opportunity to help me in presenting the outcomes of this project to local high school students or SIU students in different workshops/events (see Figures 5, Figure 6, and Section 3.e).

Include a detailed response (Do not simply respond “yes” or “no.”) to at least one of the following questions to help us understand how this project has impacted your overall university experience.

- Do you have a different understanding of sustainability now than you did at the beginning of the process?

My students involved in this project (see Figure 8) gained a better understanding about sustainability in the Power Systems. We have identified an effective storage framework for the hybrid wind-solar system to address the uncertain nature of wind speed and solar radiation.

Hence, the wind/solar energy can be harnessed more effectively to result in a cleaner energy production and mitigate our reliance on burning fossil fuels.

- Did you apply knowledge or skills learned from courses at SIU?

One of the courses the PI (Dr. Asrari) teaches at SIU is ECE 486: Clean Electric Energy. This 400-level course can be taken by undergraduate and graduate students. Three students involved in this project took this course and applied their knowledge from this course on this project. The last time this course was offered by the PI was Fall 2019.

- Did the completion of the Green Fund grant process help to prepare you for your future career opportunities?

As a matter of fact, one of the promising fields in the Power Industry is: “Integration of Wind Turbines and Solar Panels into Modern Power Systems”. The experience my students gained by accomplishing this project is a great platform for them to perform effectively in the power industry after their graduation. As mentioned, Bibek was one of the students involved in this project. He recently graduated and obtained his MS degree. He is actively looking for job opportunities in this field and I am confident he will be successful in his future career.

8. List suggestions for the SIU Sustainability Council to improve the Green Fund Award Process here:

Everything was organized. I greatly appreciate all of your efforts in supporting the ideas which can make our campus more sustainable. The recent fund-raising video was a great idea to help “potential donors understand how the Green Fund supports the university’s sustainability”.

Final Report forms should be sent electronically, in editable Microsoft Word format, to greenfund@siu.edu.

This should be completed before requesting final reimbursement. A Sustainability Council designate will review final reports before releasing funds.