Mobile Renewable Response Trailer (MRRT) for Disaster Relief Efforts

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Dr. Reg Pecen is currently a Quanta Endowed Professor of the Department of Engineering Technology at Sam Houston State University in Huntsville, Texas. Dr. Pecen was formerly a professor and program chairs of Electrical Engineering Technology and Graduate (MS and Doctoral) Programs in the Department of Technology at the University of Northern Iowa (UNI). Dr. Pecen served as 2nd President and Professor at North American University in Houston, TX from July 2012 through December 2016. He also served as a Chair of Energy Conservation and Conversion Division at American Society of Engineering Education (ASEE). Dr. Pecen holds a B.S in EE and an M.S. in Controls and Computer Engineering from the Istanbul Technical University, an M.S. in EE from the University of Colorado at Boulder, and a Ph.D. in Electrical Engineering from the University of Wyoming (UW, 1997). He served as a graduate assistant and faculty at UW, and South Dakota State University. He served on UNI Energy and Environment Council, College Diversity Committee, University Diversity Advisory Board, and Graduate College Diversity Task Force Committees. His research interests, grants, and more than 50 publications are in the areas of AC/DC Power System Interactions, distributed energy systems, power quality, and grid-connected renewable energy applications including solar and wind power systems. He is a senior member of IEEE, member of ASEE, Tau Beta Pi National Engineering Honor Society, and ATMAE. Dr. Pecen was recognized as an Honored Teacher/Researcher in "Who's Who among America's Teachers" in 2004-2009. Dr. Pecen is a recipient of 2010 Diversity Matters Award at the University of Northern Iowa for his efforts on promoting diversity and international education at UNI. He is also a recipient of 2011 UNI C.A.R.E Sustainability Award for the recognition of applied research and development of renewable energy applications at UNI and Iowa in general. Dr. Pecen established solar electric boat R & D center at UNI where dozens of students were given opportunities to design solar powered boats. UNI solar electric boat team with Dr. Pecen's supervision won two times a third place overall in World Championship on solar electric boating, an international competition promoting clean transportation technologies in US waters. He was recognized as an Advisor of the Year Award nominee among 8 other UNI faculty members in 2010-2011 academic year Leadership Award Ceremony. Dr. Pecen received a Milestone Award for outstanding mentoring of graduate students at UNI, and recognition from UNI Graduate College for acknowledging the milestone that has been achieved in successfully chairing ten or more graduate student culminating projects, theses, or dissertations, in 2011 and 2005.

He was also nominated for 2004 UNI Book and Supply Outstanding Teaching Award, March 2004, and nominated for 2006, and 2007 Russ Nielson Service Awards, UNI. Dr. Pecen is an Engineering Technology Editor of American Journal of Undergraduate Research (AJUR). He has been serving as a reviewer on the IEEE Transactions on Electronics Packaging Manufacturing since 2001. Dr. Pecen has served on ASEE Engineering Technology Division (ETD) in Annual ASEE Conferences as a reviewer, session moderator, and co-moderator since 2002. He served as a Chair-Elect on ASEE ECC Division in 2011. He also served as a program chair on ASEE ECCD in 2010. He is also serving on advisory boards of International Sustainable World Project Olympiad (isweep.org) and International Hydrogen Energy Congress. Dr. Pecen received a certificate of appreciation from IEEE Power Electronics Society in recognition of valuable contributions to the Solar Splash as 2011 and 2012 Event Coordinator. Dr. Pecen was formerly a board member of Iowa Alliance for Wind Innovation and Novel Development (www.iawind.org/board.php) and also represented UNI at Iowa Wind Energy Association (IWEA). Dr. Pecen taught Building Operator Certificate (BOC) classes for the Midwest Energy Efficiency Alliance (MEEA) since 2007 at Iowa, Kansas, Michigan, Illinois, Minnesota, and Missouri as well as the SPEER in Texas and Oklahoma to promote energy efficiency in industrial and commercial environments.

Dr. Pecen was recognized by State of Iowa Senate on June 22, 2012 for his excellent service and contribution to state of Iowa for development of clean and renewable energy and promoting diversity and international education since 1998.

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Abstract

Disasters can be as destructive as Katrina, Harvey, and Dorian leaving thousands of people homeless and without vital resources. The number of hurricanes and storms in the last decade have steadily increased in Texas leaving residents without water, electricity, and medical care. Electricity needed for emergency medical equipment is crucial to save victims' lives. In addition to traditional fossil fuel emergency generators, solar and wind energy based mobile renewable energy systems deployed with high quality and enhanced battery storage units may improve disaster relief efforts by providing quiet, reliable, and zero-emission electricity.

This paper introduces design, implementation, operation and testing of a 5.5 kW mobile renewable energy system called mobile renewable response trailer (MRRT) installed in a 20X9 feet trailer for disaster relief efforts in Texas. The MRRT contains a PV array with a rated installed power capacity of 4.4 kW, 0.3 kW wind turbine, 8x110 Ah deep-cycle battery capacity, a 2.0 kW additional emergency gas-generator, and an additional 3x1500 VA *Back-UPS* Pro Unit Uninterruptable Power System that will provide approximately a continuous load of 17-20 A for an approximate time frame of 80 hours without any charging. The funding for project was provided by a local energy company to promote Environmental initiatives for cleaner energy efforts. The MRRT is towed behind a truck and ready to be delivered to disaster-struck regions to help with the immediate needs of residents by providing emergency power including lighting, charging stations for cell phones, small tools, lifesaving medical instruments, small power equipment, Wi-Fi, and satellite services.

There are two objectives of this applied research project; (1) to provide emergency electricity for lighting, lifesaving medical equipment, and refrigeration for prescription medication to the victims of disasters in very warm and humid environments, and (2) to help underprivileged high school students and teachers at rural Independent School Districts (ISDs) to be able to access renewable energy based mobile trailer to learn a project-based hands-on energy education. The MRRT is currently being towed to multiple ISDs including rural high schools in South Texas where students and teachers excel their knowledge of energy, environmental stewardship, and storm management by hands-on learning. The U.S. Department of Education identified energy education as a priority area for the nation. In order to compete in a global society, American children need to learn more energy concepts, yet rural ISDs have few resources to help them in this endeavor. Therefore, the MRRT project will help both students and STEM teachers to increase their awareness on both engineering technology and energy education in the region.

Introduction

A number of electric utility companies in the United States maintain a state of readiness, safety, and preventive maintenance efforts before, during and after storms, hurricane and tornado seasons. Mobile energy trailers with electrical power storage, communication instruments, cell phone charging access in addition to water, food, first aid kits, and emergency medical supplies and equipment are utilized for victims living in the disaster-hit regions [1-4]. A history of mobile PV systems was discussed in detail by reporting a variety of trailer designs for different applications [2-3]. Various commercially available PV array units as well as PV-diesel hybrid units are available from electric utility companies as well as private entities for disaster relief efforts [5-7]. Another mobile solar PV unit was studied, and a prototype solar blanket with a power-conditioning module interfacing flexible PV cells to the battery for military use in harsh environments was developed [8]. A multi-purpose mobile PV solar generator providing power for running centrifugal pump in an agricultural irrigation system was developed [9]. A similar work on determining an optimum PV array rating, current and future manufacturing trends on PV emergency power generation units are also reported [10].

The Mobile Renewable Response Trailer (MRRT) is a local energy company sponsored project that allowed six undergraduate students and three faculty members to work in design, construction and implementation phases in spring and summer 2019 semesters. Fall 2019 and spring 2020 semesters include dissemination of the MRRT project by visiting nearby and regional school districts for outreach to diverse middle and high school students in metropolitan and rural school districts by providing experimental learning access to a hands-on renewable energy project to promote STEM areas and related job opportunities. The MRRT provides community outreach and education on solar and renewable power and back-up batteries technologies. It promotes renewable energy technologies at trade shows, community events, STEM fairs, and Earth Day events. A number of events have already drawn hundreds of local residents and visitors where the renewable energy trailer benefits were displayed. Educational materials and postings to summarize project commitment to renewables and environment are made available at appropriate scholarly events. In addition to a student's own drone-made video, a professional video prepared by sponsoring energy company has made the dissemination efforts of the project through social media easier.

Commercially available PV and Battery-Bank packed Trailers

Mobile Solar (MS) designs and manufactures variety of solar PV systems that capture, store and distribute electricity generated by the sun [7]. From major companies to residential applications, MS Mobile Solar generators are utilized in many fields effectively. Figure 1(a) shows MS-325, 7.2 kW rated power, 35 kWh battery capacity unit for mobile applications. Another electric utility company, EREC a touchstone energy cooperative custom made a semi-truck size bunk trailer for disaster relief efforts as seen in Figure 1(b) [6]. Worldwater and Power Company facilitated the use of one of their mobile solar PV powered water pumping and filtration systems during Hurricane Katrina [3]. Similarly as part of Hurricane Katrina recovery efforts, both Florida Solar Energy center and national Renewable Energy Center provided their mobile PV power systems for victims [3]. Figure 2 shows schematic model of a smart renewable energy micro-grid developed by *FluxGen* Engineering Technologies Company in India [10]. The flexible, scalable system can provide electricity for homes or small towns depending on PV array size. Their PV panels are wired in series and parallel combinations depending on the solar hybrid inverter specifications.

Figure 1. Commercially available mobile solar PV trailers (a) MS-325 7.2 kW rated, 35kWh battery capacity, 12 PV panels (24 kWh/day) [7], (b) FL-Escambia River Electric Cooperative (EREC) bunk trailers for disaster relief efforts [6].

The solar inverter features maximum power point tracking (MPPT), which ensures efficient power extraction from panels and stores the power in lead acid batteries as seen in Figure 2. The inverter converts the DC power in battery banks to AC power, and the control center distributes the power to residential units. The PV power system shown in Figure 2 is mostly updated to the grid-tied inverter option where the battery banks and battery maintenance issues are eliminated. The grid-tie inverters with improved synchronization features have become common choice in many recent solar PV projects.

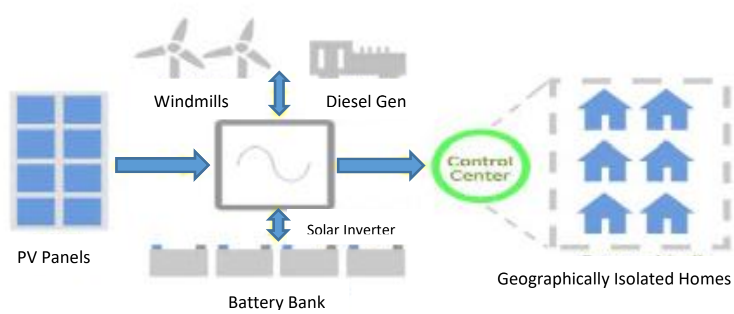

Figure 2. Schematic model of a smart renewable energy micro-grid developed by *FluxGen* Engineering Technologies Company in India [10].

Student Team Selection and Design of Mobile Renewable Response Trailer (MRRT)

Once the project external funding was secured during the beginning of January 2019, a group of six qualified junior and senior undergraduate students from the Department of Engineering Technology majors were selected among the applications for summer grant work. The PI of the grant advertised the position and brief interviews were held to select the qualified students. Four of the selected students were from Electronics and Computer Engineering Technology program with courses completed in circuits and systems, analog electronics, electrical power and machinery, control systems technology, solar and wind energy systems in addition to required Mathematics, Physics, and computer science programming courses. There were two students with design and development minor. Although majority of students started to work full-time as of June 1, 2019; two students started to work with the faculty during Spring 2019 semester for in-advanced planning and equipment and parts purchasing purposes. A conceptual design was completed during spring 2019 semester as shown in Figure 3.

Figure 3. Proposed conceptual design of MRRT project

To reduce the cost of the project, variety of existing solar PV panels are planned to be used if their current–voltage (I-V) characteristics are not causing mismatch problems. Figure 4 exhibits the custom-designed DC and AC panel board with power and control modules, protection and measurement schemes, junction boxes, charge controller, multiple inverters for main and auxiliary circuits, and finally connection to main battery bank.

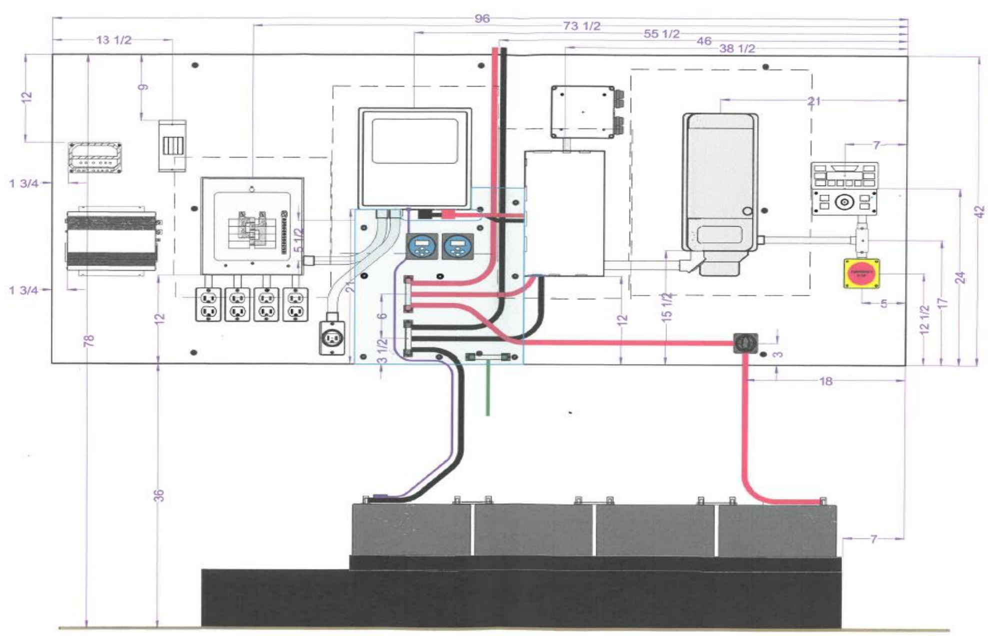

Figure 4. MRRT custom designed panel board with power and control modules and main battery bank

Initial stage of the project included proposed bill of materials (BOM), selection of vendors, and both 2D and 3D conceptual design of the proposed MRRT. Figure 5 shows students working in the MRRT project in different phases of PV and electrical system installations.

Figure 5. Student team members working in the MRRT project to precisely install PV frames and panels.

Production laboratory in the Department of Engineering Technology was the major construction area for the MRRT project. Power tools needed precise cutting, welding, drilling and installations helped students and faculty to work effectively on the project design and construction phases as seen in Figure 6.

Figure 6. PV panel steel frames are custom-cut and prepared for the installation.

PV Panel I-V Characteristics Testing and Measurements

There are four types of PV panels initially planned to be used in the MRRT project. The difference on short-circuit currents (I_{sc}) and open-circuit voltage (V_{oc}) ratings are expected to cause PV array mismatch issues. The PV mismatch issue was solved and being reported in another paper. Table I exhibits four types of PV panel rated values including rated power P (W), I_{sc} (A), and V_{oc} (V).

Table I. PV rated values for P (W), I_{sc} (A), and V_{oc} (V)

PV Panel Rated Power (W)	I_{sc} (A)	V_{oc} (V)	Irradiance (W/m^2)	Declination Angle (°)
135	9.4	20.03	840	36
230	7.5	34.5	820	37
250	7.5	35.14	820	37
310	7.33	37.6	688	37

Figure 7 exhibits the complete electrical wiring of the MRRT where three sets of PV strings are wired to a PV combiner box that is connected to a DC disconnect panel. There are two sets of deep cycle lead acid battery banks operating at 48 V voltage level. 310 W HT-SAAE type solar PV panels are the major PV modules used in the MRRT project and each PV has a maximum peak voltage of 33.6V, a maximum peak current of 9.25A, and a max power of 310W. The voltage rating for the Outback Power MATE3s 100 MPPT solar charge controller is 48V and its maximum input current is 64A. The batteries are super start marine group size 31 with the rated values of 12 VDC, 110Ah, and 550 CCA.

The major electrical equipment includes an Outback Power MATE3s charge controller, a Victron energy smart battery monitor, one AcuRite 3-in-1 weather station, custom side panel support system, custom busbar covers designed and built by students, custom MC4 connector entry box, and a custom PV panel cart. The inverter is a Magnum MS4048 type with rated values of 33A continuous AC output current at 120 V AC, and a frequency of 60 Hz. The MRRT system also includes a small wind turbine with a rated power of 0.3 kW and 48 V DC output, three sets of APC external battery packs of which 3X1,500 VA UPS capacity, and a 2 kW Westinghouse gas generator with 1.3 gallons fuel tank capacity with 13 hours of run time at 25% loading.

Figure 8 depicts actual electrical components installed on the panel board in the trailer based on the proposed design shown in Figure 4. Table II exhibits sample readings on the circuit shown in Figures 7 and 8 at variable solar irradiance levels. PV string currents as well as battery voltages are also indicated.

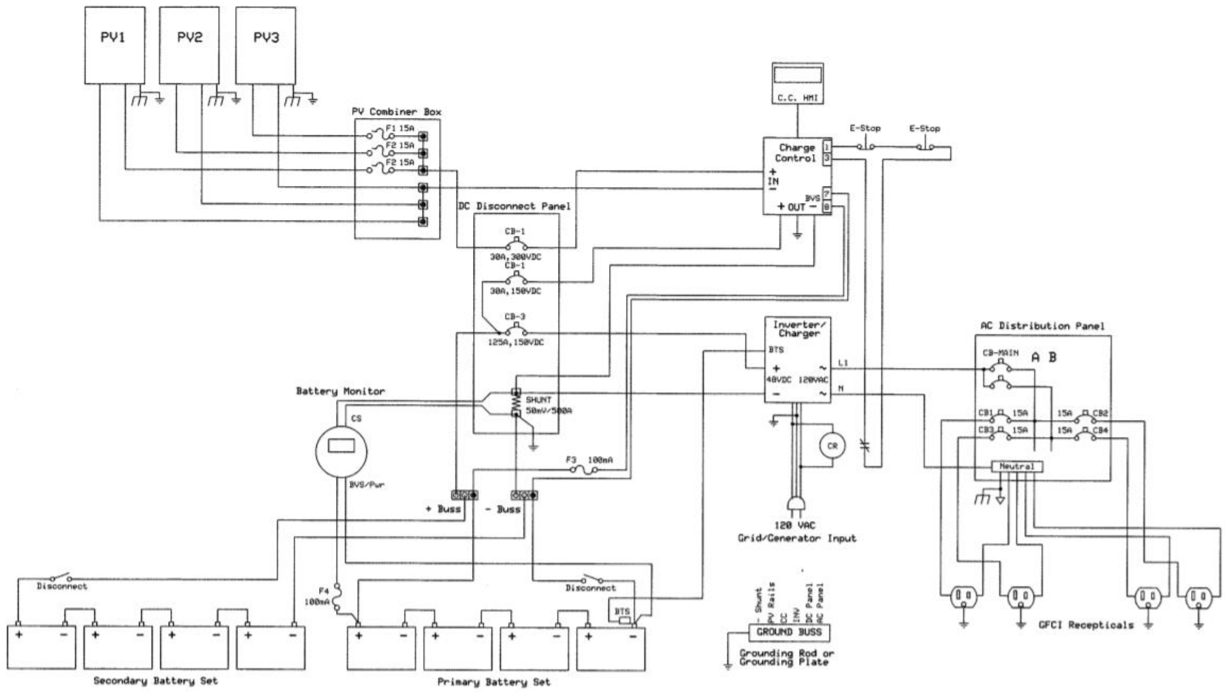

Figure 7. Wiring diagram of the electrical equipment used in the MRRT

Figure 8. Actual electrical components installed on the panel board in the trailer based on the proposed design shown in Figure 4.

Table II. Sample voltage, current and solar irradiance readings at the MRRT system

Elapsed Time Interval (hh:mm)	Solar Irradiation W/m²	Charge Controller				Manual Readings						
		PV Current	PV Voltage	Output Current	SOC (%)	PV Current			Battery Voltage			
						String 1	String 2	String 3	Battery 1	Battery 2	Battery 3	Battery 4
0:00	842	15 A	80.0 V	25.8 A	46.2	8.0 A	7.9 A	N/A	12.4 V	12.5 V	12.6 V	12.5 V
0:10	912	15A	82.2 V	25.9 A	48.5	6.3 A	9.2 A	N/A	12.6 V	12.6 V	12.6 V	12.6 V
0:20	920	15 A	83.7 V	26.1 A	51.7	6.3 A	9.0 A	N/A	12.7 V	12.7 V	12.6 V	12.6 V
0:30	923	15 A	79.8 V	25.0 A	54.8	7.6 A	7.8 A	N/A	12.8 V	12.7 V	12.7 V	12.7 V
0:40	838	-	107.0 V	-	52.0	-7.4 A	7.4 A	N/A	12.2 V	12.2 V	12.2 V	12.1 V

Figure 9 (a) depicts PV voltage and battery voltage values, and (b) PV string current and total charge controller input current during a time interval of 130 min under variable solar irradiance conditions. Similarly DC power input to the inverter and solar irradiance levels are depicted in Figure 10.

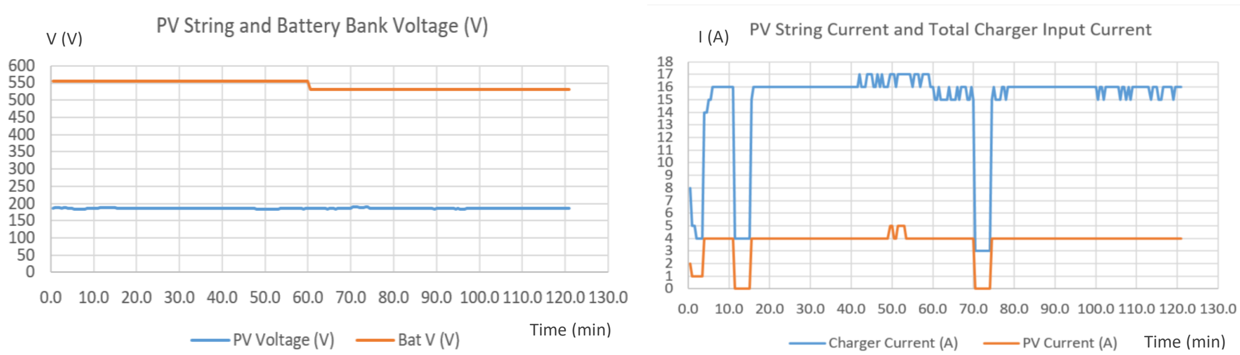

Figure 9 testing variety of operating conditions for MRRT electrical system for 130 min time interval; (a) PV string voltage and battery bank voltage, (b) PV string current and total charger input current.

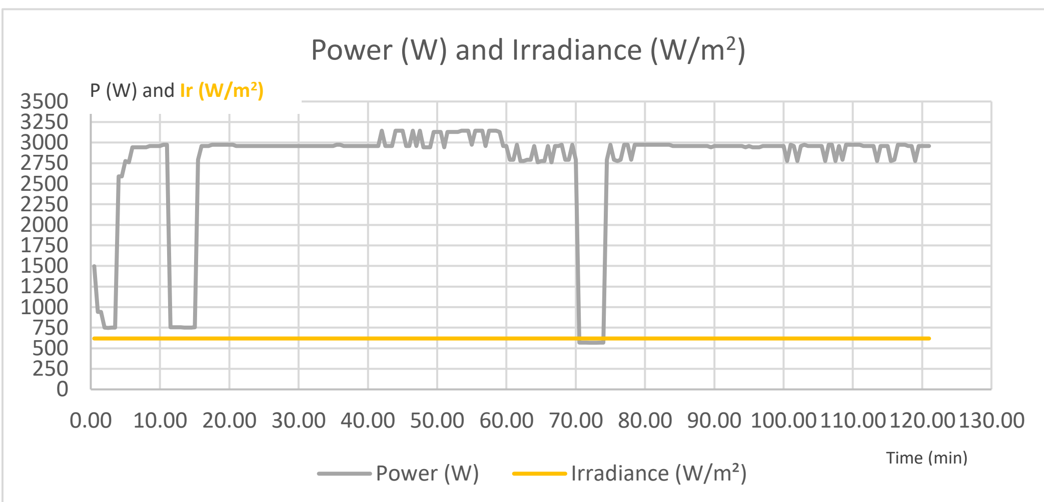

Figure 10. DC Power and Solar Irradiance values for 130 min time interval.

MRRT Project Impact to STEM Recruitment Efforts

Science, Technology, Engineering, and Mathematics (STEM) education has become increasingly central to national economic competitiveness and growth in almost every developing and developed country. Long-term strategies to maintain and increase living standards and promote opportunity will require unprecedented coordinated efforts among public, private, and non-profit entities to promote research and innovation and to prepare an adequate supply of qualified STEM workers that are capable of translating knowledge and skills into new processes, products, and services [11-12]. Specialization in STEM fields differs among countries, with the United States, European Union countries, and Japan focusing more in health sciences, while China and India specialize more in engineering and technology as measured by journal articles and conference papers [12].

The critical need for engineering education in K-12 classrooms in the United States has been highlighted in a number of reports as referenced throughout this article. Though still in its infancy, there is an emerging movement in engineering education across the country, as evidenced by the growth in STEM programs in secondary schools as well as the development and deployment of engineering curricula. However, rural school districts are often at a disadvantage without sufficient student populations, resources, or qualified teachers necessary to implement these specialized programs. Renewable energy related summer applied research programs have proven to generate more student interest and promote STEM education, especially in rural areas where there is lack of teaching tools and equipment. Due to the clear need for the engineering and science workforce in the near future, considerable numbers of educators at colleges have taken on creative recruitment and promoting activities to help increase student enrollment in STEM fields [13-14].

A study performed at University of Illinois at Urbana-Champaign [14] revealed through student surveys that some of the factors that would assist with student recruitment and retention include providing more connections to the engineering workforce; providing more orientation for incoming students; increasing the quality of instruction; improving the process of selecting teaching assistants; and improving the engineering curriculum.

One of the objectives of this applied research is to take the MRRT to school districts, specifically in rural areas of Texas, and expose students directly to the design and operations of the wind and solar PV power-based mobile power system trailer as seen in Figure 11. The targeted students were mostly high school students, although middle schools were also visited for the MRRT introduction. The MRRT trailer was also displayed in a major science and technology fair in Houston where more than 3,500 visitors had a chance to see the work [15]. Students and faculty involved in the project explain basic mathematical expressions in wind and solar PV power production and how the related parameters affect the power generation in addition to the main objective of providing emergency power to victims in disaster-hit regions. Student interest in the mobile energy system trailer, system operation and future job opportunities in wind and solar energy related careers were very high.

Figure 11. MRRT trailer is taken to STEM outreach and Engineering Technology recruitment events in various school districts in East Texas.

Student Team Weekly Progress Reports

Students working on the MRRT project are requested to regularly meet with faculty advisors for project progress and brain storming meetings on Fridays during the semester of summer 2019. Weekly progress meetings were held every Friday in the laboratory where the MRRT project was developed. A student team leader was responsible to take meeting minutes and report them project members in a technical report format. A set of sample progress reports for multiple weeks are exhibited on Table III.

Table III. Sample weekly progress reports produced and shared after each MRRT project team meeting in summer 2019.

Monday, 6/14**:* We replaced all remaining MC3 connectors on panels with new MC4 connectors, measured and cut cables for the 135 W PV panels, and mounted remaining panels onto trailer (4X 135 W PV panels). We connected all of the panels (6X230 W panels in series; 4X135 W panels in series with 2X250 W panels; 230 V panel string in parallel with the other panel string). When all of the panels are out and producing power, the maximum power produced based on the Vmp and Imp results in 2,012 W. When 2X250 W panels are removed during transportation, the 135 W panels are no longer providing power to the battery bank, as the circuit is broken, and only the 230W panels will result in a power rating of 1,381 W. Since our power has pretty much been halved during transportation, we began looking at different ways of connecting the remaining panels to optimize our power production. Our first solution was to keep the 135-W panels in parallel with the 230 W panels. In parallel, the panels would produce about 1091 W. With the 135 Wpanels in series with the 230 W panels, the power output would be roughly 1825W. Therefore, our maximum potential power output during transportation can be achieved by wiring the 135 W panels and 230 W panels in series. If we do want to have the 135 W panels in addition to the 230 W panels charging our batteries during transportation, then the easiest method might be to have a switch that changes the connection from 230 || 135 to 230 + 135. ***Friday, 6/21: Student team members continued to test the inverter and discovered that a load is needed on the AC side of the inverter in order for the inverter to output AC power. We continued to work on the overall circuit design, the layout for the stationary mounting board, and troubleshooting the Air30 turbine. ***Friday, 6/28:*** The charge controller arrived, and we began reading the manual on how to use the charge controller. We also began to discuss the inside and outside layout of the trailer as well as the electrical	the weight distribution, or to have the batteries on a metal rack near the wheel wells as the wheel wells would be the most convenient spot to provide ventilation for the batteries. The weather station was also removed from the pole outside of Westmoreland, but we have decided to purchase a new weather station that is smaller as the old one shows signs of wear and tear and would be inconvenient to mount onto the trailer. The weather station we are looking to order is the AcuRite 01530M 3-in-1 weather station with Wi-Fi connection to weather underground. The sensor provides measurements of temperature, humidity, wind speed, dew point, and heat index. The sensor combines these to give a 12 to 24 hrs forecasts of the weather. The sensor can be powered via a 5 V AC adapter or 4X non-rechargeable AA batteries. Using only the AA batteries, the sensor can run for up to two years before needing to replace the batteries. Onto the stationary mounting board, so far, we are planning to have a 6 ft X4 ft piece of plywood covered with a .060 sheet of Formica laminate. ***Friday, 7/12:*** The grounding for the trailer will be a combination of grounding plates and grounding rods. We will have both in case a location is not suitable for a placing grounding rods (i.e. hard earth, asphalt) then we will have the grounding plates. We will need to either purchase or make a set of grounding plates. Moving onto the electrical supplies, we have estimated that we will need #4 AWG wire from the charge controller to the batteries. We will also need a 60A double pole DC breaker between the charge controller and the batteries. We agreed that a junction box is a must as it will provide the most simple and convenient method for combining the solar panels. Then, between the panels and the charge controller we will need 2 x 60A single pole DC breakers, one for each string of series panels. On the output side of the inverter, a double pole, 30A breaker will be needed to prevent overcurrent from damaging the UPS systems and other AC loads. All of the breakers, AC and DC, will be contained in a central breaker box with about 6-8 slots.

equipment needed. There is a debate whether to put the batteries at the front to offset	

Conclusions

A team of Engineering Technology faculty and undergraduate students designed and built a 20X9 feet renewable energy trailer for disaster relief efforts and promoting STEM among high school students. Current and future students in the Engineering technology programs will experimentally learn energy fundamentals as well as the interconnection and back up of battery storage in solar and wind energy classes. The MRRT is currently taken to local and rural K-12 schools to teach and conduct experiments with students on renewable energy to promote environmental sustainability and STEM education. The project anticipates helping rural school students learn energy concepts and provide professional development for school teachers in the area of energy systems. The U.S. Department of Education identified energy education as a priority area for the nation. In order to compete in a global society, American children need to learn more energy and efficiency concepts, yet rural ISDs have few resources to help them in this endeavor. The current project will help both students and teachers to expand their knowledge of energy, environment, storm management, etc. as they use energy systems equipment for hands-on learning. The project will also enhance the relationship between science and the pursuit of postsecondary education for low-income rural students.

The MRRT trailer will be easily towed behind a vehicle and delivered to disaster-struck regions to help with the immediate needs of residents by providing charging stations for cell phones, lighting, cameras, small tools and power equipment and Wi-Fi and satellite services. The MRRT can also provide disaster victims enough electricity to access email and internet services, and flat mounted TV to stay up to date on news and weather. In addition, it can power lifesaving medical equipment and refrigeration for prescription medications. This is an opportunity to bring electricity, communication, information to impacted residents in times of urgent need.

The trailer will serve as a disaster-response unit providing power and support to areas hit by storms and community outreach and educational resource. Disaster response and educational materials are being designed and distributed to rural ISDs and communities explaining renewable energy and energy education. Events may draw hundreds of local residents and visitors where the MRRT benefits will be on display. The PI and Co-PI of the project are making with arrangements with the sponsor Entergy Services, Inc. regarding using the MRRT during disasters. An improved version of the MRRT containing the emergency and first aid medical equipment is also considered for commercial production purposes. Finally the MRRT also provides additional state-of-the-art laboratory activities on studying impacts of variable loads and their transient effects under multiple disturbances for a senior level solar and wind energy systems class.

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References

[1] Kondracki, R., Collins C., Habbab, K. (2014). Solar Powered Charging Station. *Proceedings ASEE 2014 Zone I Conference*, April 3-5, 2014.

[2] Qazi, S. (2017). Chapter 3 - Mobile Photovoltaic Systems for Disaster Relief and Remote Areas, Editor(s): Qazi, S., *Standalone Photovoltaic (PV) Systems for Disaster Relief and Remote Areas*, Elsevier, 2017, pp. 83-112, ISBN 9780128030226, https://doi.org/10.1016/B978-0-12-803022-6.00003-4

[3] W. R. Young (2008). "Deploying Mobile PV Emergency Power System in a Disaster," FSEC-PF-43-08, Florida Solar Energy Center. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-433-08.pdf.

[4] W.E. Alnaser, W.E. (1999). Mobile solar and wind-powered generator (MSWPG), *Elsevier Journal of Applied Energy*, Vol. 64, Issues 1–4, 1999, pp. 97-105, ISSN 0306-2619, https://doi.org/10.1016/S0306-2619(99)00055-0

[5] "SFC launches EFOY ProTrailer series for mobile hybrid power", *Fuel Cells Bulletin*, Vol. 2015, Issue 5, 2015, Page 7, ISSN 1464-2859, https://doi.org/10.1016/S1464-2859(15)30119-X

[6] EREC a touchstone energy cooperative, https://www.erec.com/energy/emergency-response/disaster-relief-travel-trailers/

[7] "MS-Series: Solar Generators," mobilesolarpower.net, http://www.mobilesolarpower.net/products/ms-series-solar-generators/

[8] K. M. Trautz, P. P. Jenkins, R. J. Walters, D. Scheiman, R. Hoheisel, R. Tatavarti, R. Chan, H. Miamoto, J. G. J. Adams, V. C. Elarde, J. Grimsley, "Mobile Solar Power," *IEEE Journal of Photovoltaics*, 3 (1) (2013) 535-541, www.researchgate.net/publication/260578261_Mobile_Solar_Power

[9] M. Majstorović, Ž. V. Despotović, L. Ristić, "Application of Mobile Solar Off-grid Generator in Irrigation System – Case Study," 19th Int. Symposium Power Electronics 2017, Novi Sad, Serbia, 2017

[10] Snankar G., Karnataki, K., Kumar T., Shodhan S. FluxGen Engineering Technologies Pvt. Ltd, North Karnataka, India. W. E. Dugger, A. F. Gilberti (2002). Standards for technological literacy: Content for the study of technology. *International Technology Education Assoc. (ITEA)*, Reston, VA.

[11] H. Tims, G. Turner, D. Schillinger. (2008). *IMELT:* Integrating mathematics, engineering, and literacy in the teaching of mathematics. *Proceedings of ASEE (American Society for Engineering Education) Annual Conference, Pittsburgh, PA.*

[12] Science and Engineering Indicators. (2019). Retrieved on January 8, 2020 from https://ncses.nsf.gov/pubs/nsb20206/

[13] R. Pecen, J. Humston, F. Yildiz F. "Promoting STEM to Young Students by Renewable Energy Applications", *Journal of STEM Education: Innovations and Research*, 13 (3), 62-73, May – June 2012.

[14] J. Johnson, L. DeStefano, and Mustari, E. (2010). Recruitment, Retention, and Performance of Students in the College of Engineering at Illinois, *40th ASEE/IEEE Frontiers in Education Conference, Oct. 27-30, 2010, Washington D.C.*, pp. S3C-1 – S3C-6, 2010.

[15] Houston Hispanic Forum, 34th Annual Career and Education Day, Saturday, February, 2020, George Brown Convention Center, Houston, Texas. https://hispanic-forum.org/