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Tabletop Microgrid Demonstration

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1. Introduction

As the challenging and controversial energy crisis continues, the design, operation, and practical use of microgrids has become an increasingly vital role for future energy alternatives. Microgrids include the use and storage of multiple renewable energy resources to power a respective community. This paper reports a unique senior design project fully sponsored by Blattner/Quanta Wind Energy company to design, construct, and test a tabletop demonstration of a microgrid 's power system. This model will showcase distributed energy generation by integrating miniature wind and solar farms for a micro-community. Additionally, this project will include model transmission lines and a battery storage unit. The integration of photovoltaic arrays and wind turbines is essential to physically show the real-time use of a scaled microgrid. One remarkable advantage offered by a microgrid is its capacity to both generate power and efficiently store clean energy. Our model will include a scaled energy storage module as a lithium-ion battery. Through design programs, such as AutoCAD and Revit, there will be a greater understanding and implementation of a microgrid 's visual aspect. Also, by having experience in foundational electrical uses, such as correct wiring and troubleshooting procedures, there will be a sophisticated finished model that will help successfully showcase a microgrid's electrical advantages in terms of stability, reliability, and resiliency. Leveraging the collective expertise and experience of our team, our model is expected to be a showcase for the practical and advantageous utilization of a microgrid.

2. Problem Definition

The requirements for a microgrid demonstration project can be divided into three categories: performance, safety, and education. Our performance requirement is that the system meets the expected quantitative and qualitative needs to ensure reliable generation, storage, and distribution within the table-top demonstration. This project also conveys educational content, facilitating the engagement and understanding with the concepts of electrical power distribution and efficient micro-grid operation. The model will comply with electrical safety regulations by including limits of voltage, current, etc. To promote sustainable practices, the model will incorporate sustainable design elements. This includes energy efficiency, resource conservation, and lifecycle assessment. The target group of this applied project is students in both engineering and engineering technology programs.

Blattner Company, project sponsor required multiple specifications and constraints in the project. The table design should encompass specific elements integral to the project. This includes 3-4 wind turbines, some operational while others are at various stages of construction for demonstration purposes for their audience. Similarly, there should be a functioning solar farm alongside one in the process of being built. The illustration should distinctly feature trades relevant to the project, such as foundation work, installation, electrical setup, and civil engineering aspects. Furthermore, the table's design must effectively simulate potential hazards, such as the presence of animals entering the construction site in a real wind-solar farm in the remote areas. Ensuring the preservation of land and habitat remains a key priority throughout the representation. Additionally, the table needs to incorporate essential components like transmission lines, a substation, a battery energy storage system (BESS), a river, railroad tracks, a crane, and roads to accurately depict the project's infrastructure and logistics. The microgrid demonstration unit is to be located in an open area with available day light that provides solar energy applied to PV arrays. The wind turbines rated speed is about 5-7 mph wind to be provided by a nearby wind tunnel. The wind turbines can also be operated as a motor from battery-based DC power storage.

3. Literature Review

In the pursuit of a tabletop microgrid demonstration project, it is imperative to establish a comprehensive understanding of the key concepts and components involved.

Microgrid Concept:

A microgrid represents a sophisticated energy distribution system designed to enhance the reliability, resiliency, and efficiency of power supply within a localized area. The concept of microgrid was initially presented in the technical literature by Lasseter [1-3] as a solution to integrate distributed energy resources, including Energy Storage Systems (ESSs) and controlled loads reliably. There are a number of definitions of microgrids in the engineering literature [3-4]. The basic definition of a microgrid by the U.S. Department of Energy is "A group of interconnected loads and Distributed Energy Resources (DERs) within clearly defined electrical boundaries that acts as a single controllable entity concerning the grid. A microgrid can connect and disconnect from the larger utility grid to operate in either grid-connected or island mode" [5]. Contrary to conventional centralized grids, microgrids are primarily developed to handle and integrate distributed energy resources, allowing them to serve their loads locally without the need for costly transmission infrastructure. It comprises a network of interconnected loads and distributed energy resources (DERs), such as solar and wind farms, and energy storage systems. The microgrid as a flexible solution for the deployment of DERs, is a promising direction from which to approach the five D goals listed as decentralization, decarbonization, democratization, deregulation and digitalization. These components are orchestrated in a manner that allows the microgrid to function seamlessly in two primary modes:

Grid-Connected Mode: In this operational state, the microgrid is synchronized with the larger utility grid, drawing power from it and, when necessary, feeding excess energy back into the grid. This mode is instrumental in optimizing energy efficiency and can enable cost savings through demand response and peak shaving strategies.

1. Islanded Mode: In the event of a grid outage or as a deliberate response to grid instability, the microgrid can autonomously disconnect from the main grid and operate in isolation. This islanded mode ensures continued electricity supply to critical loads, such as hospitals, data centers, and emergency services, offering a significant boost to grid resilience.

The Microgrid (MG) Exchange Group within the U.S. Department of Energy states that the microgrid "operates as a controllable structure to the main grid and is constrained within well- defined electrical boundaries [5]." The concept of a microgrid is established by advanced control systems and communication technologies. These systems enable the microgrid to manage power generation, distribution, and consumption efficiently while ensuring voltage and frequency stability within the defined electrical boundaries. Additionally, advanced control algorithms facilitate seamless transitions between grid-connected and islanded modes, optimizing the use of available energy resources. As a controllable structure within the larger grid framework, rnicrogrids have accumulated substantial interest due to their potential to address various energy challenges, including enhancing grid reliability, integrating renewable energy sources, and mitigating the impacts of natural disasters and grid disturbances. This comprehensive understanding of microgrids encompasses their dual operational modes and their pivotal role in modernizing and fortifying energy distribution systems, rendering them increasingly relevant in a rapidly evolving energy landscape [6-7].

Distributed Generation:

Distributed generation (DG), as defined, represents a shift in the generation and distribution of electricity. It is characterized by the production of electricity in close proximity to the point of consumption, thereby deviating from the traditional centralized generation model. This transformative approach to energy generation is known by several interchangeable terms, including "decentralization generation," "on-site generation," and "distributed energy" [6]. The spectrum of technologies and systems encompassed by distributed generation is both diverse and dynamic. It encompasses a wide array of energy sources and generation technologies, each tailored to specific applications and local requirements. These include, but are not limited to:

1. Co-Generators: Co-generation systems, also known as combined heat and power (CHP) systems, produce both electricity and useful heat from a single energy source, such as natural gas or biomass. They are highly efficient and often used in industrial and commercial settings to simultaneously meet electrical and thermal energy needs.
2. Photovoltaic (PV) Panels: PV panels, which convert sunlight into electricity, have gained significant traction in distributed generation. They are commonly installed on rooftops, building facades, and even integrated into building materials, allowing for the direct generation of electricity at or near the point of consumption.
3. Small Wind Turbines: Small-scale wind turbines harness wind energy to generate electricity. They are particularly suitable for distributed generation in areas with favorable wind conditions, including residential, agricultural, and remote locations.
4. Emergency Generators: Emergency generators, often powered by diesel or natural gas, provide backup power during grid outages or in critical facilities where uninterrupted electricity supply is essential.
5. Small-Scale Hydro Plants: Micro-hydroelectric plants harness the energy of flowing water in streams or rivers to generate electricity. They are employed in regions with access to water resources, offering a sustainable source of distributed power.
6. Energy Storage Systems: Energy storage technologies, such as batteries, play a crucial role in distributed generation by storing excess electricity. These stored energies can be discharged during high demand periods or power outages, ensuring a stable and reliable electricity supply for consumers.

DG offers several advantages, including enhanced energy resiliency, reduced transmission and distribution losses, and the potential for increased integration of renewable energy sources. Moreover, it can support grid stability and reliability by reducing strain on centralized generation and transmission infrastructure. The concept of distributed generation is pivotal in addressing the evolving energy landscape, characterized by a growing emphasis on sustainability, grid modernization, and decentralized energy production. By generating electricity closer to the point of use, distributed generation is at the forefront of transforming the way we produce and consume energy [8-10]. Hybrid renewable energy systems combine multiple sources of renewable energy, such as solar and wind, to enhance overall system efficiency and reliability. They also capture renewable energy from the sun and wind, respectively, and convert it into electricity through PV cells and wind turbines. Hybrid systems combine these energy sources with energy storage to create a more reliable and efficient power generation solution, particularly useful for microgrid applications [11-12].

Energy Storage Systems:

Energy storage systems (ESS) play a pivotal and indispensable role in ensuring the reliable and stable operation of microgrids [10-13]. This importance stems from the inherent challenge associated with renewable energy sources, namely their intermittent nature [12-13]. Renewable resources such as solar and wind power are subject to fluctuations due to weather conditions, which can result in periods of surplus energy generation followed by deficits. This variability poses a significant challenge in matching energy supply with demand, especially in microgrid environments where grid connection may be intermittent or absent. ESS addresses this challenge by serving as a crucial buffer, enabling microgrids to capture and store excess energy during periods of high generation and release it when demand exceeds supply. This dynamic interaction between generation, storage, and distribution enhances the microgrid's ability to balance energy supply and demand, thereby bolstering grid stability and ensuring a consistent power supply. Energy storage systems facilitate the optimization of renewable energy utilization by allowing microgrids to enhance grid resilience by rapidly responding to fluctuation in renewable generation so that ESS can mitigate the impact of sudden changes in weather conditions. Regarding the diverse range of energy storage technologies, various options exist to address specific microgrid requirements and operational challenges. Liu *et al.* and Lima *et al.* explain several technologies suitable for renewable energy storage, including [12-13]. In summary, energy storage systems serve as the anchor of microgrid operation, addressing the intermittent of renewable energy sources and ensuring a stable and resilient energy supply. Their versatility in technology options allows microgrid operators to tailor their ESS solutions to specific environmental conditions, load profiles, and grid requirements [12-13].

Majority of microgrid studies are heavily involved in system design, implementation of a new methodologies, operation, and enhancement to the conventional grid that will improve reliability, stability and resiliency of the existing overall power grid. Educational research in terms of promoting and adopting undergraduate level microgrid studies are limited. The authors previously worked on a small-scale microgrid design and implementation to introduce in an undergraduate level electrical power system course [14-16]. One of the major motivations of this applied project is direct sponsorship from one major wind and solar energy company, Blattner Inc., in the nation and the company's need for a visually attractive microgrid system to educate young minds and citizens touring the facilities.

4. Engineering Approach

Our desktop microgrid design concept integrates five wind turbines and two solar farms outlined on a 7x3 ft table as seen in Figure 1. In this visualization, red turbines indicate those under construction, while blue turbines signify operational status. Similarly, one solar farm will be operational while the other is in the construction phase. To optimize layout efficiency, the BESS and substation will be positioned between the two solar farms, as illustrated in Figure 1. In addition, tar roads will flank either side of the solar farms, with a connecting road situated between them. This road network will enhance accessibility and connectivity within the visual representation of the microgrid system. These planned features aim to provide a comprehensive and visually engaging demonstration of the microgrid infrastructure and its operational dynamics. Furthermore, on the right side of this setup, a farmhouse with animals will be included. To signify the operational status of the wind and solar farms, a light will be incorporated into the farmhouse, indicating their functionality. Figure 2 illustrates a concept for integrating the river and railroad. A removable board with finger holes will feature on the left side of the table. One side of the board will depict a railroad, while flipping it over will reveal a representation of a river. This design element adds versatility to the demonstration setup. Through these proposed design enhancements, our team aims to meet the necessary requirements for an illustrative and comprehensive table-top demonstration of the microgrid system.

Figure 3 presents the block diagram of the project. Our design incorporates 12 Vdc generators for both wind turbines. The solar farm consists of three branches of two solar panels each, utilizing solar panels with an output of 6 V and 6 W. Through a series-para11el combination, this configuration yields an output of 12 Vdc, aligning with the wind turbines. The hybrid charge controller acts as the central hub in our system, receiving inputs from both the wind turbines and solar farm simultaneously. It orchestrates power distribution to the BESS, featuring a 20 Ah lithium-ion battery, and then to the substation, which combines the functions of an inverter and a transformer. Following this, the inverter converts 12 Vdc to 24 Vac, with subsequent voltage amplification to 120 Vac facilitated by a step-up transformer.

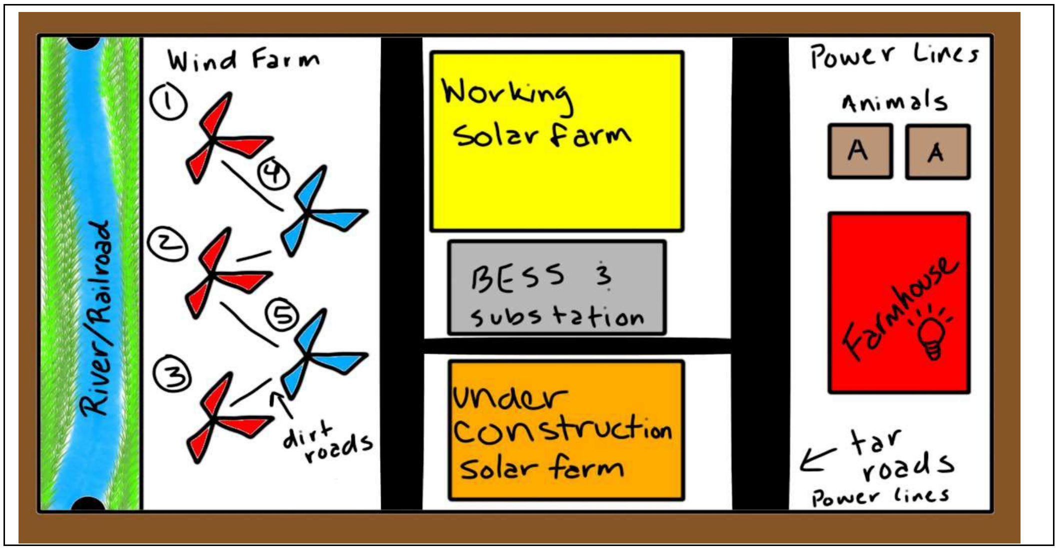

Figure 1. Rough sketch for proposed project.

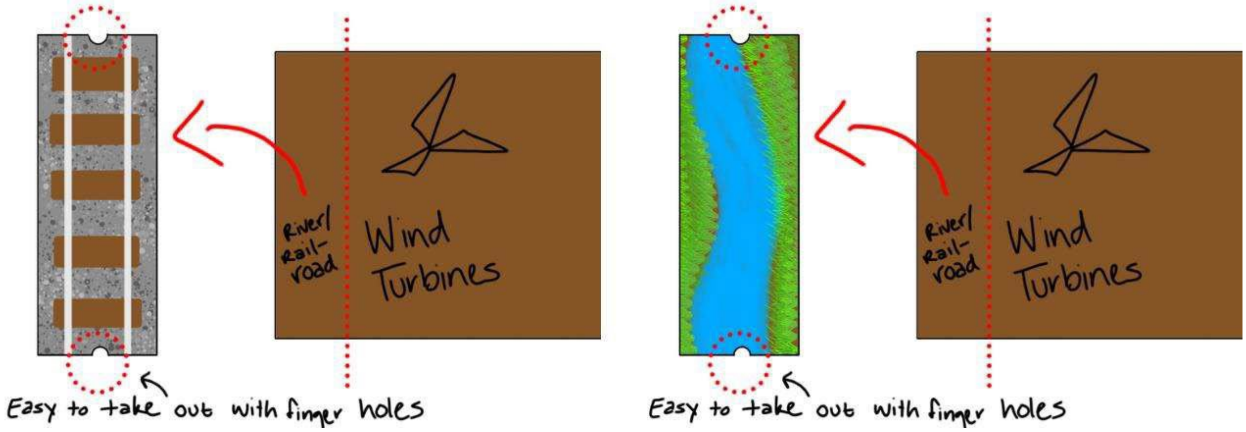

Figure 2. Rough sketch for river and railroad idea.

This progression ensures seamless power transmission through the lines to fulfill the designated load requirements. This sequential connection ensures an integrated flow of power from the renewable sources through essential control points and energy conversion mechanisms towards supplying the designated load. The schematic depiction exhibits the coherent process and pivotal components involved in harnessing and transmitting energy from wind and solar resources for practical utilization.

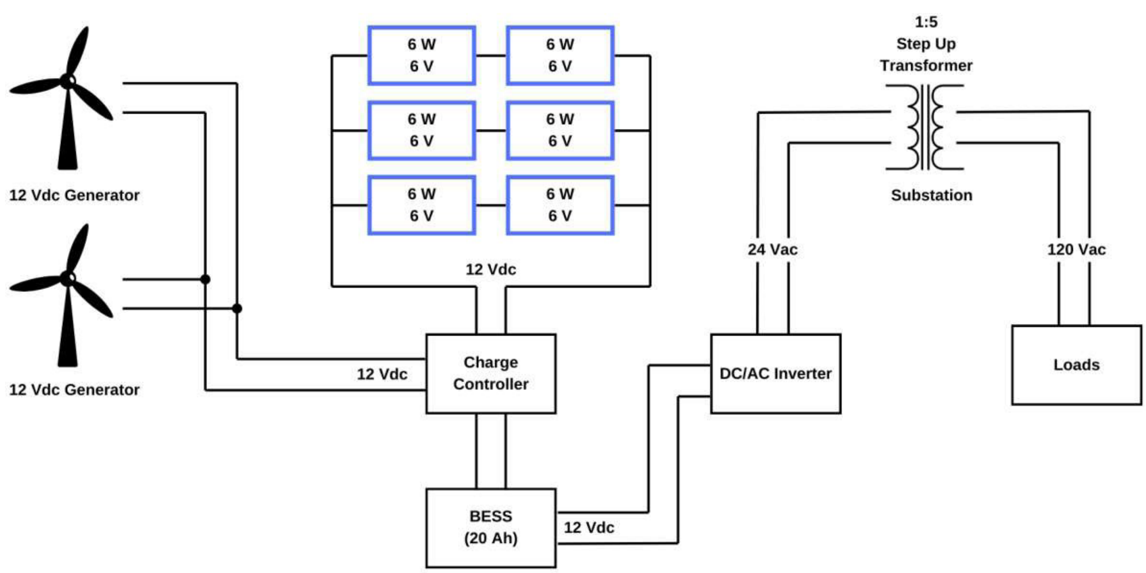

Figure 3. Block Diagram of the overall microgrid.

Figure 4 presents a comprehensive 3D model displaying the layout of the wind farm, featuring three turbines under construction on the left and two fully operational turbines on the right. Each wind turbine's construction will utilize 3D printing technology, primarily employing plastic components for ease of assembly. These turbines will be designed in modular pieces, akin to a puzzle, allowing seamless integration during assembly. Within each turbine, a compact 12 Vdc generator will be incorporated, linked to an internal wiring infrastructure. As the turbine blades rotate, this movement generates electricity, subsequently directed through the internal wiring system.

The generated electrical power will be routed through these wires and stored within a lithium-ion battery, denoted as the BESS in Figure 4a. Complementing the miniature wind farm, our microgrid concept will include two solar farms. Utilizing 3D printing, miniature stands will be crafted to support the solar panels. These stands will serve a dual purpose by not only providing support but also concealing the wiring connections to the houses and the storage battery. The integrated lithium-ion battery in the microgrid system can store energy, enabling it to supply power to the houses upon activation of a switch. This switch represents the response to an interference event such as a hazard or a natural disaster, showcasing the microgrid's ability to swiftly provide backup power during emergencies. This storage mechanism plays a pivotal role within the microgrid, allowing efficient energy storage for later use. Additionally, the wiring infrastructure extends to the farmhouse depicted in Figure 4b. This interconnected loop exemplifies the microgrid's capability to store surplus power, ensuring a reliable backup power supply during emergencies. This emphasizes the system's resilience and self-sufficiency, showcasing its capacity to efficiently store and utilize excess energy.

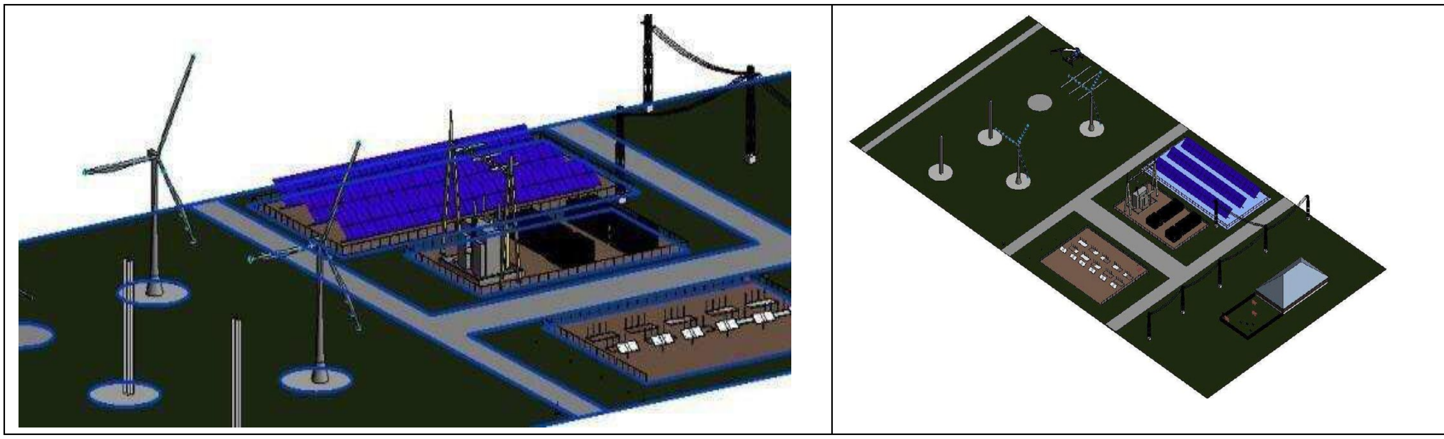

Figure 4a 3D model of wind and solar farm, BESS, and Figure 4b a substation and farmhouse.

5. Tasks and Deliverables

The engineering approach for our project focused on optimizing the functionality of a scaled microgrid table while prioritizing mobility and flexibility. The table's construction used plywood as the primary material to ensure durability and practicality in various operational settings. We designed the table to be meticulously crafted to meet the demands of mobility and flexibility. Key features included the integration of wheels for easy movement within the workspace and folding legs to provide dual functionality as both a conventional table and a tabletop. While our initial plan outlined a table measuring 7 feet in length by 3 feet in width, minor adjustments were made during the execution phase. The final dimensions were optimized to 7 feet in length and 3.5 feet in width to accommodate the folding mechanism effectively without compromising stability. This modification ensured that the table maintained its structural integrity while offering enhanced usability. An essential aspect of our engineering approach was to prioritize storage and accessibility. By incorporating folding features into both the legs and tabletop, the table could be conveniently stored in a compact form when not in use.

Once the table construction was complete, our focus shifted to the electrical components. One significant challenge arose when determining the construction of a wind turbine around a 12 Vdc generator, along with the accompanying gears. When students presented the project in the class and shared their challenge of designing and 3D printing gearbox and turbine/generator cases, one mechanical engineering technology student offered to construct the gearboxes and turbines with 3D-printed cases as seen in Figure 5. Beneath the table, there is a designated hole through which the wires pass to connect to the rest of the components. Due to constraints posed by the wind turbines' size, we decided to reduce the number from five to three. Among these, two turbines will be operational, while the third will be depicted as under construction.

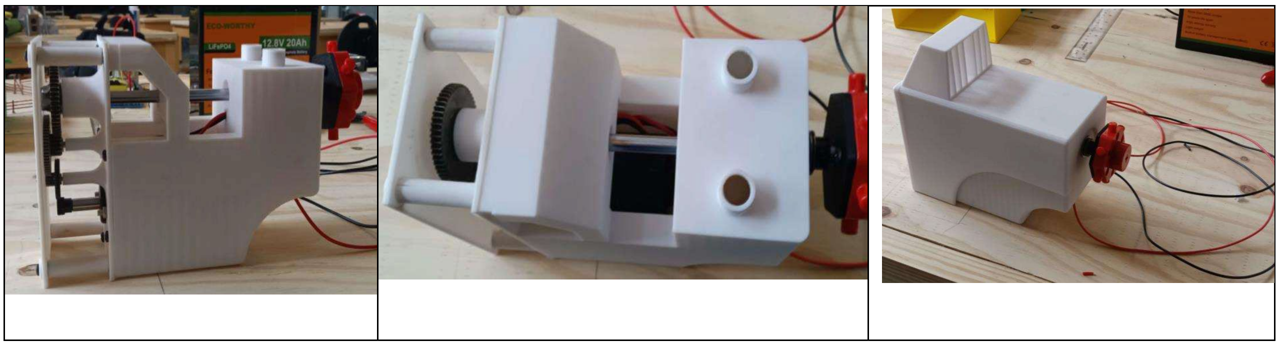

Figure 5. Gear Box and wind turbine generator components and their protective cases.

In the subsequent phase of the project, our focus turned to the solar farm. We embarked on designing and 3D printing holders tailored for solar panels. Following this, we utilized a drill to create partial holes in the table, allowing the solar panel holders to sit seamlessly within the table's surface. This design choice ensures easy removal and reattachment of the solar panels as needed. The wires were carefully soldered onto the back of the solar panels to align with the circuit wiring depicted in Figure 6. Figures 7a and 7b exhibit the solar panels securely mounted and wired onto the table. Like the approach adopted for the wind turbines, the wires leading to the solar panels pass through holes in the solar panel holders and then through designated holes in the table, facilitating connection to the remaining components of the circuit.

The charge controller is strategically mounted underneath the table, serving as a central hub for our system. Moving forward, we initiated the wiring process for the remaining components. To accommodate the lithium-ion battery, we cut a hole in the table, allowing the battery to be partially embedded. The battery is securely held in place using plumber's strap, and a 3D-printed cover was created for added protection. Given the size limitations of 3D printers, we once again enlisted MET student's assistance, utilizing his personal 3D printer for the task. Following the battery's connection to the charge controller, we encountered a hurdle with the inverter. Initially uncertain about achieving the desired 24 Vac output, students turned to instructional videos for guidance. Utilizing a voltmeter to test various soldering points, students eventually determined that pinpoints VO and V7 for appropriate (step-up) voltage levels in the substation transformer terminals to provide the required output to the AC loads as seen in Figure 3. Figure 6 illustrates the PV array, charge controller, battery storage, and inverter to the AC loads.

Concurrently with the wiring process, we embarked on 3D modeling power line poles, which were subsequently 3D printed and meticulously painted to resemble realistic wood. To further enhance authenticity, we affixed pieces of terminal blocks onto the power line poles. From the car inverter, the wire was routed to the power line poles to facilitate transmission to the loads. Employing a similar approach as with the solar panel holders, we partially cut into the table to seamlessly accommodate the power poles, allowing for easy placement and removal as needed. This meticulous attention to detail ensured both functionality and aesthetic coherence within our demonstration setup. From the power line poles, the wires traverse through the house to establish connection with the first load, a 120 Vac LED light. Subsequently, this LED light is further connected to another LED light located in the farm area, with the wiring discreetly routed underneath the table to maintain a neat and organized setup. This sequential connection ensures efficient power distribution to the designated loads, facilitating the operational demonstration of the microgrid system's capabilities. However, the challenging effort required to turn the wind turbines led to the turbine/generator's inability to produce voltage. This setback prompted us to reassess our wiring design, as depicted in the block diagram in Figure 3. Consequently, we opted for a revised approach, implementing two separate circuits: one dedicated to the wind turbines and another for the remaining components. diagram specifically tailored for the wind turbines. As part of this adjustment, we decided to integrate a second lithium-ion battery directly connected to the wind turbines, allowing for a demonstration of their movement. The sole modification from the original block diagram involves the substitution of an inverter and transformer with a car inverter.

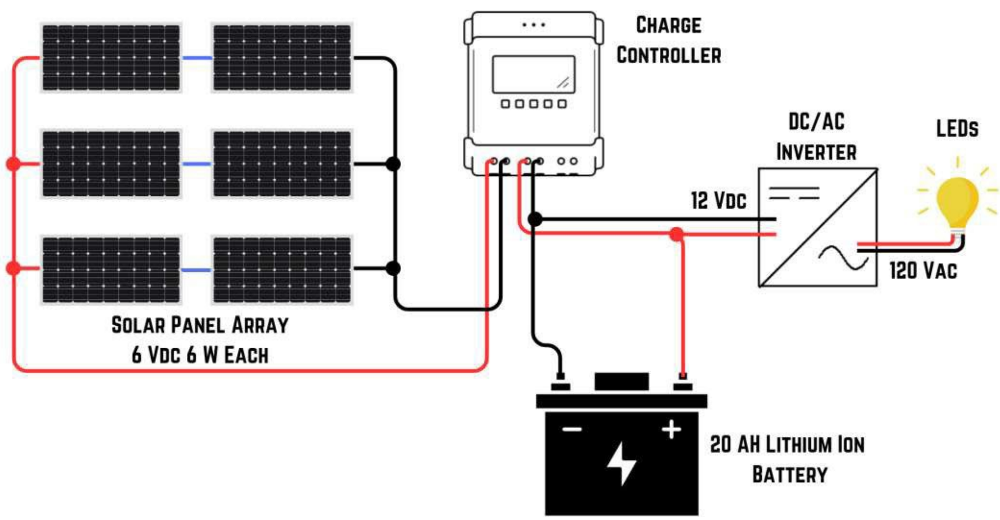

Figure 6 . PV Arrays Circuit Wiring Diagram.

After completing and ensuring the functionality of the wiring, we shifted our focus to enhancing the aesthetics to achieve maximum realism. As a final touch, we integrated three toggle switches, a digital voltmeter, and a digital ammeter onto the table. The first toggle switch governs the operation of the wind turbines. When activated, it enables the turbines to spin, replicating the motion of actual turbines. The second switch regulates the digital ammeter, providing readouts of voltage and current after the car inverter. Lastly, the third switch not only governs the digital voltmeter display, revealing the voltage of the battery connected to the solar panels and car inverter but also activates the LED lights in both the house and barn. Figures 7a and 7b provide visual representations of different sections on the table and functional integration of components to craft a realistic and captivating demonstration setup.

Figure 7a Tabletop microgrid system with farmhouse and overhead power lines 7b. Completed desktop microgrid system with solar farm, wind farm, and BESS sections.

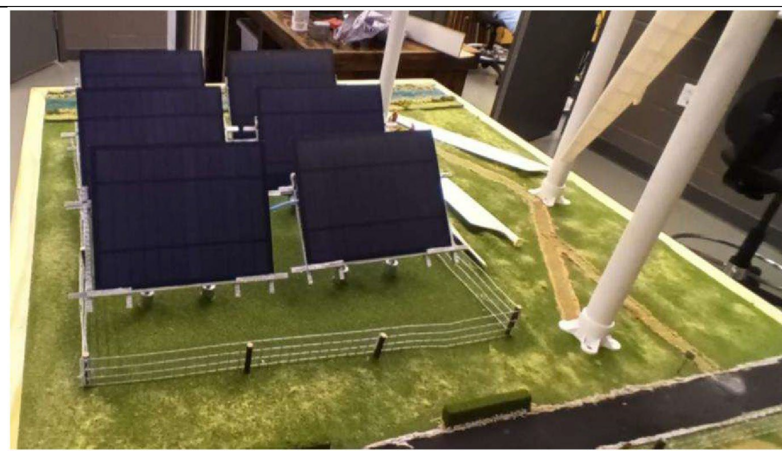

Figure 8a Solar and wind farm and cable harness under the desktop. 8b. Solar PV arrays modeling the solar farm.

6. Project Management

In addition to three senior students from different majors; electrical, mechanical, and engineering design, another MET student worked on the project. As the interdisciplinary students worked on this project, the synergy among the students were very high. While the tabletop design with model home, farm, animals, roads, etc. were solely designed and built by a design student with arts minor; one MET student specifically worked on all 3D design and prints as wells as all electromechanical system design and testing. Electronics and Computer Engineering Technology student was responsible for all electrical design, wiring, testing and troubleshooting. This student was also responsible to move the entire system to Blattner Company's show room in Denver, Colorado, to install and prepare for demonstrations.

Faculty and students regularly met on Zoom with Blattner/Quanta Energy engineer and university relations manager to regularly monitor the project. During fall semester when the proposal phase was in progress, the team met biweekly and during spring semester when the project implementation and construction in progress, the team met weekly. The team's endeavor commenced with thorough research into topics crucial to our proposed project. Transitioning into the design phase, the team translated conceptualizations into tangible forms through the creation of detailed 3D models. Subsequently, the team devised a circuit schematic, illuminating the interconnections among pivotal project components, a fundamental aspect for demonstration purposes. Progressing into phase two, the development stage, the team members successfully executed tasks such as completing the bill of materials and assembling the table.

Leveraging 3D printing technology, the team fabricated essential components and meticulously integrated them onto the table. Upon completion of phase two, our focus shifted to phase three - the testing phase. The team rigorously evaluated project's functionality and efficiency, iterating as necessary to ensure optimal performance. This phase represented a critical juncture in validating the viability and effectiveness of our project's implementation. Lastly, the team focused on enhancing the table's realism through embellishments. The project was allocated a budget of $3,500, with only $2,237.18 utilized. With the cost of shipping and travel expenses of student to move the tabletop micro system to Colorado, overall cost reached to about $4,500. Table 1 provides a detailed breakdown of expenses, outlining the costs and materials acquired within this allocated budget except the shipping and travel expenses.

Table 1 Project Budget

Material	Cost	Quantity	Total Cost
DC Generators	$43.99	5	$219.9
Solar Panels	$16.99	12	$203.8
Charge Controller	$148.15	2	$296.3
Lithium Ion Battery	$59.99	2	$119.9
DC/AC Inverter	$19.61	2	$39.2
Transformer	$19.99	2	$39.9
Toggle Switches	$13.99	1	$13.9
120 Vac LED Light	$21.99	1	$21.9
Digital Voltmeter	$6.99	1	$6.9
Amp Meter	$19.98	1	$19.9
14 Gauge Wire	$17.99	2	$35.9
PVC Flange	$13.69	1	$13.6
4 mm x 300 mm Rod	$7.59	1	$7.5
3 mm x 100 mm Rod	$5.49	1	$5.4
8 mm x 100 mm Rod	$11.99	1	$11.9
Thrust Needle Roller Bearings	$9.49	1	$9.4
Lock Collar	$8.99	1	$8.9
Flanged Ball Bearing	$10.09	1	$10.0
Substation Accessories	$43.99	1	$43.9
Fine Buff Gravel	$10.62	2	$21.24
Chain Fence	$14.58	5	$72.90
Maintenance Workers	$18.17	2	$36.34
Yard Crew	$17.49	2	$34.98
Traffic Cones	$9.69	3	$29.07
Traffic Signs	$8.07	2	$16.14
Railroad Workers	$17.49	2	$39.98
Foam Sheets	$5.89	2	$11.78
Cows	$10.99	2	$21.98
Farmhouse Kit	$41.38	1	$41.38
Rustic Fence and Gate	$11.68	2	$23.36
Static Grass	$9.22	3	$27.66
Railway	$29.99	1	$29.99
Railway Scenery	$10.99	2	$21.98
Bushes and Trees	$13.75	2	$27.50
Grass Terrain	$13.99	2	$27.98
Sand Terrain	$18.99	2	$37.98
Grass Tufts	$25.99	2	$51.98
½ 2x4 Sande Plywood	$14.94	1	$14.94

Material	Cost	Quantity	Total Cost
Fake Grass	$19.99	2	$38.98
Railroads	$9.99	2	$19.98
Hinges	$4.93	3	$14.79
Plywood	$44.00	1	$44.00
2x4x8 Dimensional Lumber	$3.25	16	$52.00
2x6x8 Dimensional Lumber	$3.83	5	$19.15
Caster Wheels	$14.68	4	$58.72
2.5 Inch Screws	$8.98	2	$17.96
6 Inch ½ in Hex Bolt	$47.48	1	$47.48
Nuts	$13.38	1	$13.38
Washers	$12.15	1	$12.15
Plumber's Strap	$6.46	1	$6.46
Piano Strap Hinge	$13.98	1	$13.98
½ Screws	$6.98	1	$6.98
3D Print Filament	$18.00	3	$54.00
Art Supplies	$85.49	N/A	$85.49
Gray Spray Paint	$5.98	1	$5.98
Metallic Spray Paint	$6.98	1	$6.98

Total: $2,237.18 of $3,500

7. Student Assessment

The senior design project presented in this paper is one of the 18 capstone projects completed in the 2023-2024 academic year. The project included multidisciplinary students from Sam Houston State University, Electronics and Computer Engineering Technology, Mechanical Engineering Technology, and Engineering Design Technology programs in the Department of Engineering Technology. Engineering Technology programs contain five Student Learning Outcomes (SLOs) and their corresponding fourteen Key Performance Indicators (KPIs) that are all measured for completed capstone projects. Out of five SLOs, assessment results for SLO2 entitled as "design systems, components, or processes meeting specified needs for broadly defined engineering problems appropriate to the ECET discipline" is shown on Table 2. SLOs 1-5 and their standard deviations for Senior design II course are also reported below.

Table 2. Sample assessment selected.

SLO 2. Design systems, components, or processes meeting specified needs for broadly defined engineering problems appropriate to the ECET discipline.

Key Performance Indicators	Unsatisfactory < 60%	Developing 60-69%	Satisfactory 70-79%	Exemplary >80%
a) Identify problem, criteria, constraints	0	0	40%	60%
b) Define the problem, review possible solutions, select design	0	0	35%	65%

c) Design, assess, refine and conclude the model or prototype	0	0	50%	50%
Indicate possible data collection items (i.e. lectures, assignments, quizzes, lab reports, projects, test questions) that may be used by the department in the annual assessment: *Senior Design Projects; average of one initial report, one midterm report, and one final technical report.*				

Total number of students assessed (N_s): 44 during Spring 2024, 0 student earned D/F.		
SLO 1: Apply knowledge, techniques, skills and modern tools of mathematics, science, engineering, and technology to solve broadly defined engineering problems appropriate to the ECET discipline.	Average (M_s): Final Tech. Report: 88.9%	Standard deviation (σ_s): Final Tech. Report: 7.8
SLO 2: Design systems, components, or processes meeting specified needs for broadly defined engineering problems appropriate to the ECET discipline.	Average (M_s): Final Tech. Report: 85.7%	Standard deviation (σ_s): Final Tech. Report: 7.8
SLO 3: Apply written, oral, and graphical communication in broadly defined technical and non-technical environments; and an ability to identify and use appropriate technical literature.	Average (M_s): Average of Final Tech Report and Final Presentation: 91.8%	Standard deviation (σ_s): Average of Final Tech Report and Final Presentation: 11.6
SLO 4: Conduct standard tests, measurements, and experiments and to analyze and interpret the results to improve processes.	Average (M_s): Average Prog. Rep. : 99.3%	Standard deviation (σ_s): Average Prog. Rep. : 3.2

SLO 5: Function effectively as a member as well as a leader on technical teams.	Average (M_s): Average of Final Tech Report and Final Presentation: 92.4%	Standard deviation (σ_s): Average of Final Tech Report and Final Presentation: 11.6
Total Grading	Average (M_s): Final Grade: 89.6% (Before Curve)	Standard deviation (σ_s): Final Grade: 3.8 (Before Curve)

Students worked and contributed this project also stated their satisfaction on preparing themselves on real-life engineering challenges while working on externally sponsored project. They also mentioned that describing their senior design project work and their project success stories were their most comfortable and convenient part of their interview with many companies.

8. Conclusion

In conclusion, this project serves as a proactive response to the prevailing challenges posed by the energy crisis. It centers on the meticulous design, construction, and rigorous testing of a tabletop microgrid demonstration. In today's dynamic energy landscape, there's an imperative need for innovative solutions that bolster reliability, resilience, and efficiency in power distribution. This senior design project is positioned to address these critical objectives by offering a compelling showcase of microgrid capabilities through a visually engaging and fully functional model. Through this endeavor, the team members aim to contribute to the advancement of sustainable and resilient energy solutions, showcasing the potential of microgrids in meeting the evolving demands of modem power systems.

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