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Conversion of a Golf Cart into A Solar Photovoltaic Powered Vehicle

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Abstract

This project engages undergraduate engineering technology students in the innovative conversion of a non-operational three-row golf cart into a sustainable vehicle powered by solar photovoltaic (PV) technology. While the technical goal was to restore and enhance the cart's functionality, the educational objective centered on providing students with a unique, hands-on opportunity to integrate renewable energy systems into a practical design challenge. By combining applied research and experiential learning, the project serves as a model for advancing sustainability-focused engineering education.

The conversion process required students to retrofit the existing cart structure with flexible solar panels, strategically mounted on the roof, to capture solar energy and charge a battery system. The battery provided the primary power source for the electric drive components. This hybrid configuration enabled students to analyze system-level integration issues, such as balancing energy flow, optimizing storage, and ensuring reliable operation. Students are engaged in iterative design, simulation, and testing cycles, applying concepts learned in coursework to real-world engineering decisions. Performance metrics, including energy efficiency, operational range, charging times, and system reliability were systematically collected and evaluated by students. These analyses not only assessed the technical effectiveness of the hybrid solar PV system but also provided students with experience in data driven problem solving and experimental validation. Students documented challenges such as energy conversion losses, component compatibility, and weather-dependent variability, using these experiences to develop critical engineering judgment.

Beyond the technical outcomes, the project emphasized professional and educational skill development. Students worked in interdisciplinary teams, practicing collaboration, communication, and project management. They gained exposure to emerging renewable energy technologies, while also grappling with the broader implications of sustainable transportation in engineering practice. Faculty mentorship guided the project, but students were responsible for key design decisions, encouraging independence, creativity, and ownership of the learning process.

The results of this project demonstrate dual impacts. Technically, the golf cart conversion showcases the feasibility of combining solar and grid power technologies into small scale electric mobility solutions. Educationally, the project highlights how student-led, sustainability-centered research can be integrated into engineering curricula to strengthen problem-based learning, bridge theory and practice, and prepare students for careers in renewable energy and green technology sectors. Future iterations of this work will explore scaling the model to other student projects, developing structured learning modules around hybrid energy systems, and disseminating best practices for embedding sustainability-focused projects in engineering education.

INTRODUCTION

The golf cart recovery and rebuilding project at Sam Houston State University began with a vision to integrate renewable energy into practical transportation. As part of the engineering technology department's ongoing research, this project aimed to convert a standard golf cart into a solar-powered vehicle. Its purpose extended beyond technical innovation; the cart would demonstrate the potential of renewable energy, serving as a functional tool for campus sustainability efforts and an engaging centerpiece during tours. Solar energy was chosen for its alignment with the department's focus on clean energy solutions, promoting environmental awareness while inspiring future engineers.

The foundation of this project started with the recovery of a disused golf cart from the Property Maintenance Department. Although structurally intact, the cart was in poor condition due to prolonged outdoor storage, requiring extensive cleaning and replacement of its damaged upholstery. Beyond restoration, the project aimed to reinvent the cart as a solar-powered vehicle, a concept symbolic of innovation and environmental stewardship. The initiative became a collaborative effort within the university, emphasizing sustainability and advancing renewable energy and electric vehicle research.

The integration of solar panels on golf carts presents an innovative solution to reduce environmental impact, enhance energy efficiency, and extend the usability of these vehicles. Providing clean power for a golf cart is only a small step into the future of powering a hybrid vehicle. Here we get to perform design considerations, integration challenges, simulations, and real-world testing. This project also serves as a learning experience for students to better understand power management, using space efficiently, and enhancing designs. And to further thought for sustainable transportation solutions, showcasing potential benefits of combined energy systems.

The recent increasing demand for clean and renewable energy sources has led to the exploration and push for innovative solutions for various applications, especially in transportation. In this multi-phase project, we focused on the integration of solar panels onto a golf cart to harness solar energy while in motion on a sunny day, as well as to reduce the reliance on gasoline powered motors. According to the International Energy Agency the share of renewables in global electricity generation jumped to 29% in 2020 [1]. In recent years, an increasing number of financial incentive programs have been enacted to promote renewable energy systems, encouraging on-site renewable generation to maximize cost savings and reduce stress on the electric grid. [2]. Information and Communication Technology (ICT) has been impacting renewable energy by facilitating data collection and analysis, making it easier for investors to make decisions based on up-to-date information. ICT also works on simplifying communication and collaboration between experts and other stakeholders [3]. In this project we are working on a hybrid golf cart, and with that we must think about energy management strategies, and energy storage systems. Hybrid vehicles must deal with high variability in energy demand, including frequent rapid acceleration and deceleration phases, which can negatively affect battery cycle life and, in turn, increase overall vehicle maintenance costs. [4]. With this project, the main goal is to teach young minds to think about innovations in hybrid electric vehicles. The need for innovation is driven by the goal of promoting economic prosperity and environmental sustainability, enabling governments to advance renewable energy projects more effectively. The primary reason for the low level of government commitment is the high cost, which places the country’s vehicle manufacturing industry at a disadvantage in the global marketplace [5].

PROBLEM STATEMENTS AND SOLUTIONS

The problems described below were identified by the student design team through direct evaluation of the golf cart platform during the early design phase of the project. This process included physical inspection of the cart, dimensional measurements of the available roof area, power requirement analysis of the 6.7 HP motor (≈5 kW), and structural assessment of the fiberglass roof and its supporting members. Through this engineering analysis, the team identified key constraints, including limited surface area for solar panels, weight distribution and stability concerns, mechanical challenges associated with panel angling and deployment, and structural inadequacy of the existing roof system to safely support additional loads.

- Problem 1.1: The Limited Surface Area - Golf carts have limited surface area for solar panel installation, making it difficult to generate sufficient power. If the solar panel were to be laid flat as one layer, only four solar panels would be able to fit. This would produce only 690 watts of power, while the 6.7 HP motor requires an estimated 5 KW of power.
- Problem 1.2: The weight and effort of balancing the additional solar panels can affect the weight distribution and balance of the golf cart, potentially compromising its stability.
- Problem 1.3: The problem arose around the fact on how to angle the solar panels properly without the solar panels falling due to gravity yet also having the ability to be drawn out without interfering with one another. There were many ideas proposed but most required more parts being added therefore adding to the overall cost, weight, complexity, and maintenance.
- Problem 2.1: The original roof is not designed to carry weight in mind and given that the roof is made of fiberglass the problem of leaks becomes a real problem. And the stability of the roof also comes into question since the metals support bars holding the roof will have a hard time holding more than 200-300 pounds. Also, more frightening is the fact that the metal bar is attached to the seats of cart which means the weight of roof will be more dependent on the bolts of the front seats of the cart. Which means the front seat would be under a lot of stress from the additional weight from the solar panels and would most likely mean a structure failure and possible injury. As seen below, the roof is also inadequate for equally distributing weight on its roof with the horizontal bars on the top (Figure 1). It creates an awkward shape with some parts no longer straightening because of wear and tear from the environment. The roof also needs added support to keep the structure of the roof from deforming given that roof is made of fiber glass.

Figure 1 – a) The roof top of the golf cart, water and physical minor damages can be seen. b) The support bars on the golf cart. c) The under belly of the roof, supported by a cage to maintain its shape.

The solutions presented below were developed through an iterative, student-driven design process. After defining the constraints, the team engaged in structured brainstorming sessions to generate multiple conceptual approaches. Concepts were evaluated based on feasibility, cost, added weight, structural safety, and mechanical complexity. For example, the stacked, pull-out solar panel configuration (Solution 1.1) was proposed to address the limited surface area constraint. The opposing sliding directions and distributed placement strategy (Solution 1.2) were introduced to mitigate imbalance and load concentration concerns. The rail-and-wheel angling mechanism (Solution 1.3) evolved after considering several alternatives and was informed by design inspirations from existing DIY and commercial solar systems. Finally, roof reinforcement and structural redesign options (Solution 2.1) were proposed in response to the identified load-bearing limitations and safety risks. These solutions were the result of student-led conceptual design, engineering calculations, trade-off analysis, and iterative refinement rather than predefined instructor-imposed answers.

- <u>Solution 1.1:</u> The project idea was to layer the solar panels into a stack of three to later pull them out like a drawer to maximum surface area for the solar panels by a factor of three. And to conduct more efficiently, the plan is to also add a function where you can angle the solar panels.
- <u>Solution 1.2:</u> Careful design and placement design of the solar panel array with consideration for weight distribution. With the added feature to draw out the solar panels, the planning and design came down to drawing the solar planes in opposite directions to cancel out the forces acting on the golf cart. Distribute panels where the supporting rod is located is to minimize the additional weight on unsupported potions of the roof and balance issues. Computer simulations and testing should be used to validate the design.
- <u>Solution 1.3:</u> Based on the design, the angle will be performed by two wheels attached to the back of the solar panels. To prevent the solar panels from falling out of the rails, the two wheels on the back of the solar panels will be of larger size (1.5" diameter). While the front wheels will be of a small size (1" diameter) and the idea is to add a blocking area that prevents the back wheels from leaving the rails while the front wheels can freely move in and out of the rails. This solution became possible from inspirations of other people's DIY on their own solar project or even to big company solar projects [6-8].
- <u>Solution 2.1:</u> The best course of action is to reinforce the roof by providing more support. This could be done by adding support beams to help with the weight issue. Also, the idea of replacing the roof with the same roof materials comes to mind since the current roof is dented and curved and may have water damage meaning the roof is in a weakened state. Another idea would be to make a brand-new roof with solar panels in mind to support the additional weight. Also adding more stable support beams throughout the available space of the cart ground, to better distribute the load put upon the roof. If a new roof Is made that would give room to better attach the support beams that are bolted to the front seats and are not in fact welded together, to rather weld these beams to the proper frame of the golf cart to provide better stability and strength (Figure 2).

Figure 2 – a) The rear end of the golf cart supports bars. b) Seating and side frame of the golf cart. c) The front end of the golf cart.

LOAD ANALYSIS AND SIMULATION

A similar replica of the golf cart is modeled using SolidWorks for load analysis. The body of the golf cart (set as a fixture) material was set as steel alloy and the roof as PF material including setting up 200 Newtons on multiple points on the roof. After several executions of analysis, the result of strain shows the possible displacement given the stress. Creating a valley in the middle of the roof, while hinting that the edge of the roof would experience some displacement (Figure 3).

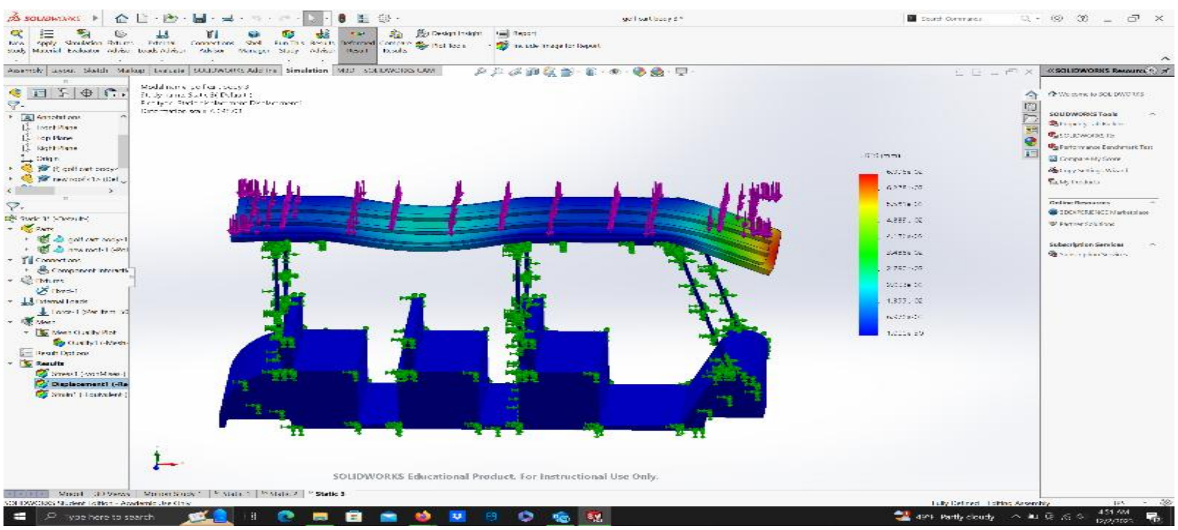

Figure 3 Simulation of the displacement on the roof

In Figure 3, the Displacement simulation identified two weak points. The first being on the very front of the roof and the second being on the middle of the roof. Adding a metal frame to top of the vehicle and it confirms that reinforcing the roof would be necessary in the case of installation of nine solar panels. The figures below also depict strain and stress simulations to identify weaknesses before implementation of the project (Figure 4-5).

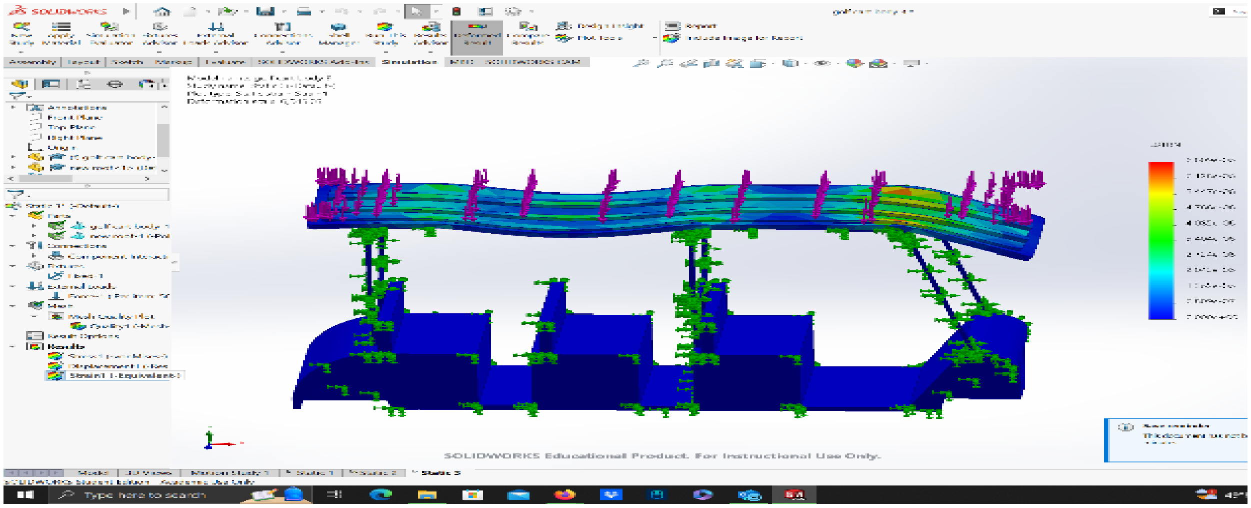

Figure 4 Simulation of the strain on the roof

The Strain simulation shows the possible displacement given the stress. Creating a valley in the middle of the roof, while hinting that the edge of the roof would experience some displacement.

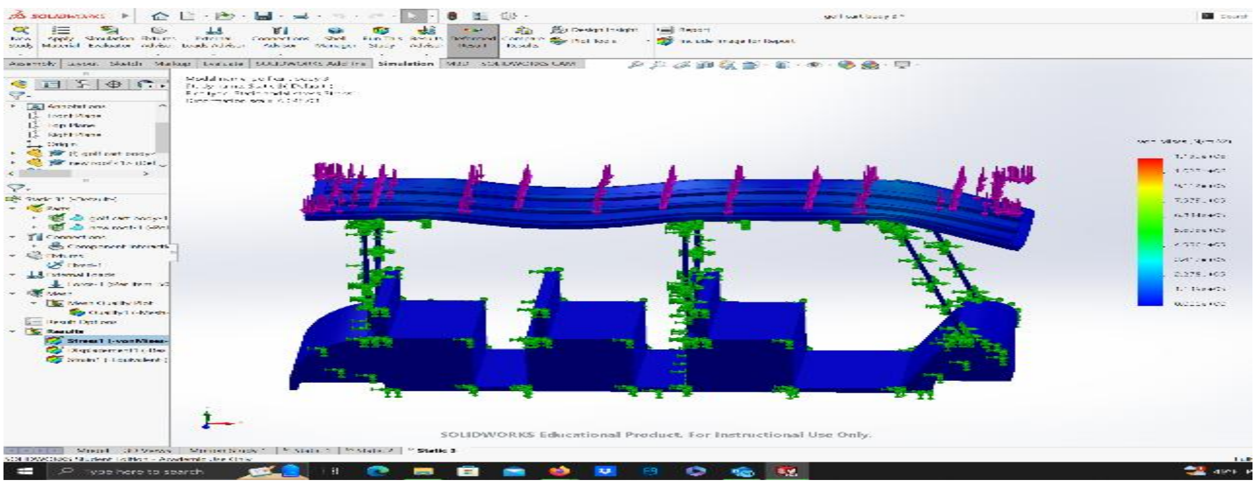

Figure 5 Simulation of the stress on the roof

The stress simulation shows some stress will be experienced where the support bar and the roof meet. Further simulations to check if adding a support beam will help with the load. The simulation came to look funnier looking, but it does show that adding some support beams would help in the area where the rails of the solar panels frame will be sitting (Figure 6).

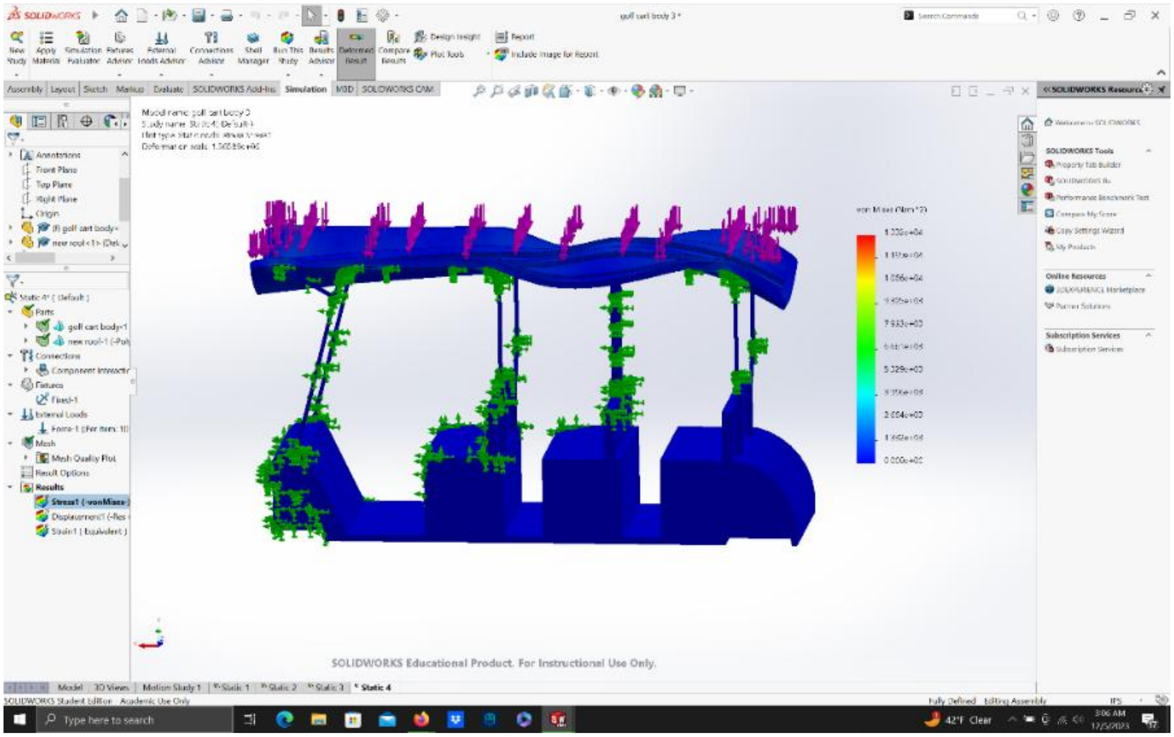

Figure 6a – Stress simulation, each purple arrow is applying 10 N of force, while green means the object is fixed.

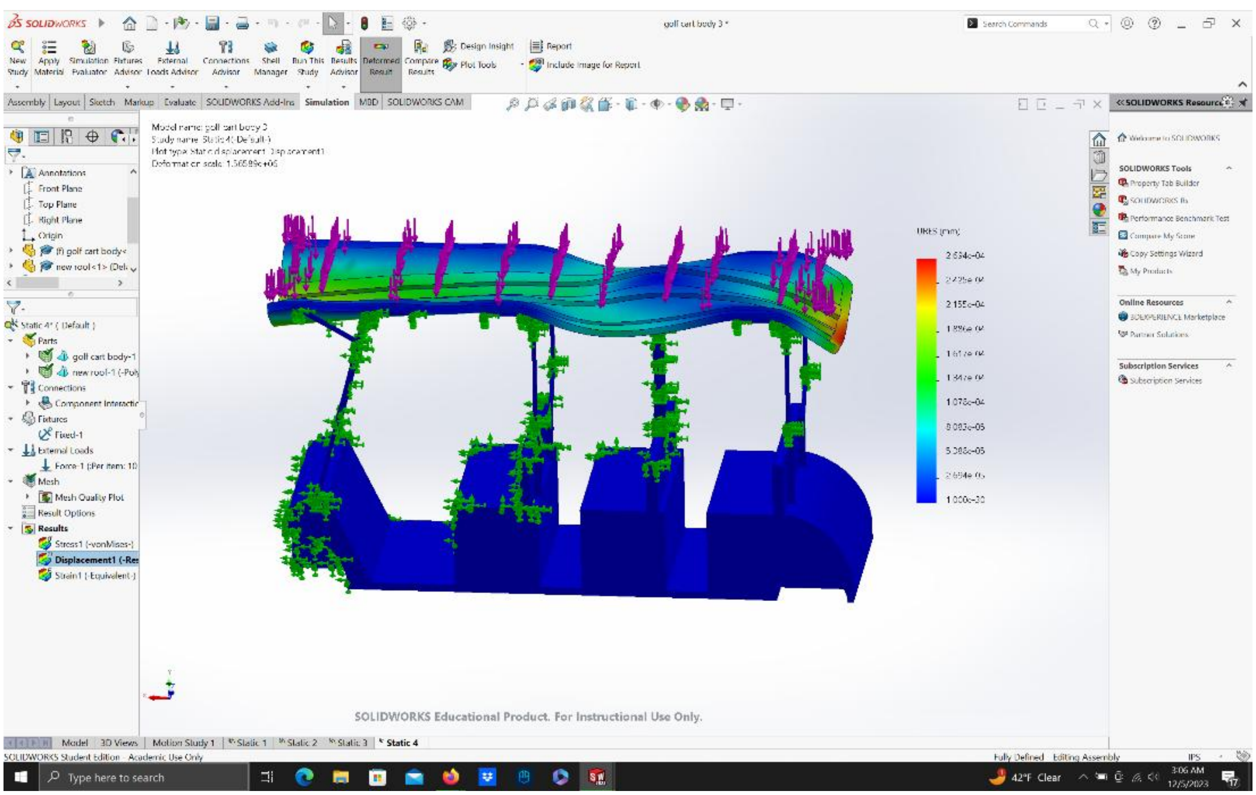

Figure 6b –Displacement simulation

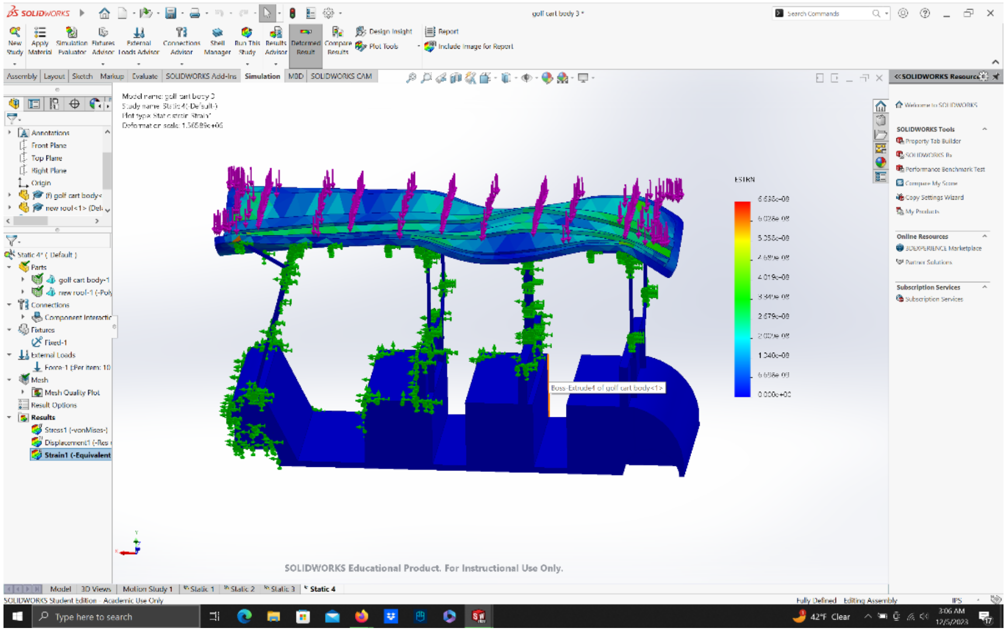

Figure 6c – Strain simulation

BRACKET AND SOLAR ARRAY DESIGN

One of the project's most critical phases was designing and installing the solar array, which represented the primary power source for the golf cart. The system was configured to deliver a 48V charge using four solar panels arranged in two sets of two panels connected in series. The configuration choice allowed the panels to integrate seamlessly with the cart’s electrical system, optimizing energy transfer and functionality.

When making the design, the idea was to get angled metals to make rail for the wheel to be able to draw the solar panels in opposite directions (Figure 7). Then later the idea of adding a metal sheet near the solar panels to hold the solar panels in place. Adding a ramp for the front of the solar panels with smaller wheels to have the ability to draw the solar panels while also having the ability to angle the solar panels. The problem arises that the front needed a sheet of metal to be able to swing from the left to the right to stop them.


Figure 7a– Side rails from a front angle

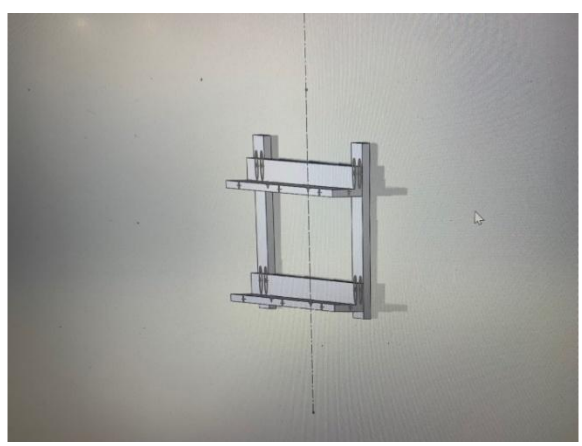
Figure 7b - Side rails from a side angle

The team then experimented with an aluminum awning-style bracket to mount the solar panels. While innovative, this design posed a significant issue: it raised the center of gravity too high, creating a tipping hazard during operation. Recognizing the safety risks, the team pivoted to a low-rise steel frame. This alternative design proved more stable and practical, enabling smaller, lighter, and stronger solar panels without compromising the cart's structural integrity. The new design enhanced stability and ensured that the solar array met the performance requirements.

Figure 8 shows the CAD design of the aluminum awning-style bracket for mounting solar panels. While innovative, this design raised the center of gravity too high, creating a tipping hazard during operation, and was ultimately replaced with a low-rise steel frame. Figure 9 captures the process of reinforcing the golf cart roof for structural stability and installing the low-rise steel frame. This design ensures a secure and stable mount for the solar panels while maintaining a low center of gravity for safe operation.

Figure 8 Solar Awning design

Figure 9: Process of Roof Reinforcing

The wiring beneath the solar panels was secured using adhesive-backed Velcro straps attached to the underside of the panels. These straps were strategically positioned to allow free movement of the sliding solar panel mechanism while preventing wire entanglement during deployment and retraction. The frame design incorporated sufficient spacing to accommodate safe cable routes and mechanical clearance. During the assembly phase, the team carefully reviewed the final design and addressed emerging concerns. Students demonstrated the use of various fabrication tools and equipment, including cutting, edge finishing, and steel welding techniques. Additionally, specialized screw assemblies were selected and modified to ensure proper rail alignment without interfering with the wheel mechanism (Figure 10).

Figure 10. A Front and side view of the frame made.

There were some concerns that the roof could not hold the weight of the solar panels. The solution was to go around and attach bars and brackets to the main support bars and then make railing for the solar panels array to sit on. As seen in Figure 11, the step was to weld most of the parts together. The only parts not welded together were the array and the bars, instead we went ahead to bolt them together.

Figure 11 – a) A side view of the added bars. b) A front view of the welded bars. c) Side view of the bars.

The following is a list of materials used to build the support structure.

130 inches length steel bar that is 1 inch by 1 inch. (top rails)
20 inches length steel bar that is 1 inch by 1 inch (Side brackets)
6 X 48 inches of aluminum angled by 1 inch by inch
2 X 35 inches of aluminum angled by ¼ inch by ¼ inch

ELECTRICAL SYSTEM REBUILD

The Golf cart has to be planned around the electrical specs. It being a 48-volt AC motor that can generate 6.7 HP. Seating capacity of 6. With a max speed of 19 mph. The cart's electrical system underwent a comprehensive overhaul to restore its functionality and improve performance. This phase included replacing the failed motor controller and addressing wiring issues. The original wiring configuration was largely retained, but individual components such as the motor, accelerator, and wiring were disassembled and tested for faults. Faulty parts were replaced, and new wiring was installed to ensure seamless connectivity between components.

To evaluate energy storage and efficiency, the team tested two types of batteries: the Optima 8016-103 CBC D34M BlueTop (AGM lead-acid) and the KiloVault 1200 HLX (Lithium Iron Phosphate). The AGM battery offered durability and vibration resistance, but its energy density and efficiency were limited. Conversely, the $LiFePO_4$ battery excelled in energy storage, discharge cycles, and overall efficiency, making it the superior choice for this application.

The system integrates a shunt motor controller to regulate power delivery from the battery banks to the shunt motor, ensuring efficient energy utilization. Control inputs from the key switch and pedal are routed through the solenoid, enabling precise operational control. The color-coded wiring highlights the energy flow from solar generation to storage and motor propulsion, showcasing the seamless integration of renewable energy and advanced battery technology to achieve a sustainable transportation solution. Figure 12 depicts wiring diagram of the electrical system. This schematic illustrates the electrical system design for the solar-powered golf cart. Four solar panels, configured in a series-parallel arrangement, generate a 48V charge to power two distinct battery banks: primary $LiFePO_4$ batteries (KiloVault 1200 HLX) and secondary AGM batteries (Optima D34M BlueTop).

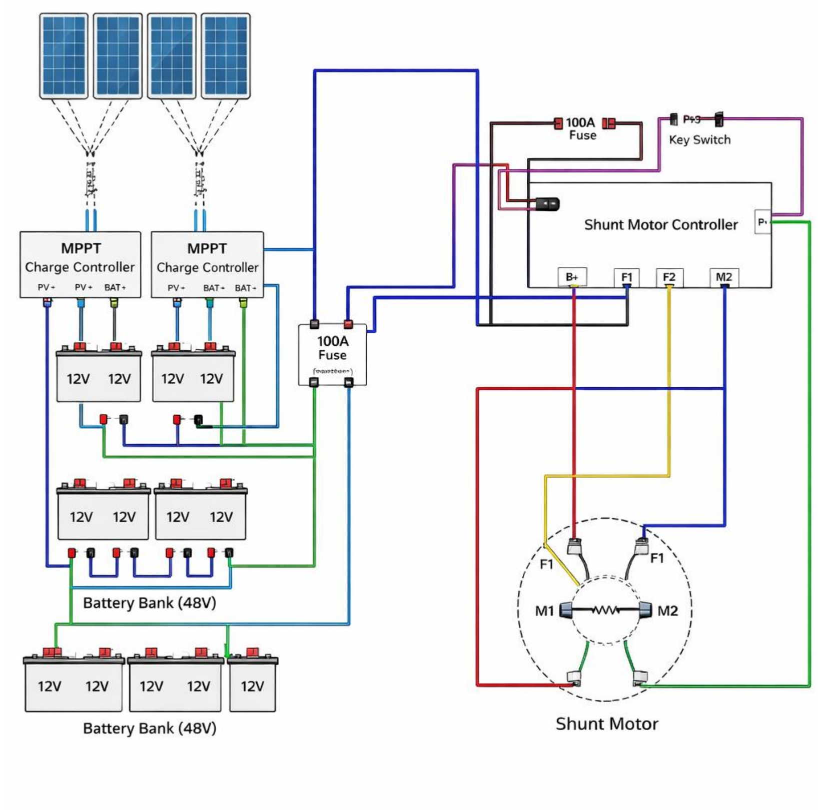

Figure 12. Electrical Diagram

Table 1 provides a comprehensive overview of the key components, their electrical specifications, quantities, and roles within the solar-powered golf cart system.

Table 1: Electrical Components

Part Name	Description	Voltage (V)	Current (A)	Power (W)	Quantity	Notes
Solar Panels	Canadian Solar (CS6P-230P)	29.6	7.78 per panel	230 per panel	4	Total output of 920W (4 panels x 230W).
$LiFePO_4$ Battery (KiloVault 1200 HLX)	Lithium Iron Phosphate battery with superior performance	12.8	Continuous discharge: 100	1,280 per battery	4	Configured in series to achieve a 48V system. Each battery

	and efficiency.					has a capacity of 100Ah.
Motor Controller	Restores functionality to the golf cart's electrical system.	48	Supports up to 200-400 peak	Supports motors up to ~10,000	1	Ensure proper operation of the golf cart motor.
Solar Charge Controller (ATO-PWM)	Regulates solar energy and charges the battery bank	48 (input)	Rated for 20-30	N/A	1	Matches solar panel output; configured to charge 48V battery bank.
System Integration Tools	Tools and software for controller programming and diagnostics.	N/A	N/A	N/A	1	Includes Alltrax XCT Controller Toolkit for system optimization.

Note: The KiloVault 1200 HLX batteries are configured in series to achieve a 48V system, providing a total capacity of 100Ah at 48V.

ONGOING IMPROVEMENTS

Although the golf cart rebuild project successfully transformed a nonfunctional vehicle into a solar-powered system, there is still significant potential for optimization and expansion. One of the most promising enhancements involves integrating a hydrogen fuel cell system. By adding this component, the cart could gain an auxiliary power source that would ensure consistent energy output during periods of low sunlight or high energy demand. This improvement would complement the solar array, reduce downtime and further increase the cart's range and reliability.

Another area for improvement lies in refining the solar array design. Testing new, more efficient photovoltaic technologies or exploring dynamic mounting systems that track sunlight could greatly enhance energy capture. Additionally, optimizing battery performance remains a priority. Conducting extended-use tests and analyzing results under a broader range of conditions would help identify further opportunities to improve energy management and efficiency. Looking forward, the project team also envisions the potential to adapt to this renewable energy system for other lightweight vehicles, thereby broadening the impact of their findings and advancing clean transportation solutions.

CONCLUSION

The solar-powered golf cart project demonstrates both technical feasibility and meaningful educational impact while clearly distinguishing student-led work from faculty mentorship. The project serves as a replicable model for integrating renewable energy systems into undergraduate engineering technology curricula where students enrolled in directed/independent study courses to be part of the project.

Students were responsible for the core engineering activities throughout the project lifecycle. They defined the problem constraints, conducted power requirement calculations, evaluated surface area and structural limitations, performed trade-off analyses, selected components (solar panels, charge controllers, batteries, motor controller), designed the mounting structure, developed the sliding and angling mechanisms, completed fabrication and welding tasks, performed wiring and system integration, and conducted functional testing and troubleshooting. Students also evaluated battery performance (including comparison of Lithium Iron Phosphate batteries), assessed solar charging capability under real-world conditions, and proposed structural reinforcement solutions based on observed load limitations.

Faculty mentor served in an advisory and supervisory capacity. Their role focused on guiding the design process, ensuring adherence to safety standards, verifying engineering calculations, approving final design decisions before fabrication, facilitating access to laboratory resources, and providing structured feedback during design reviews. Faculty intervention was limited to maintaining safety, feasibility, and compliance with institutional requirements while preserving student ownership of engineering decisions.

Project evaluation included both technical and educational components. Technical assessment, conducted jointly by students and faculty, examined system functionality, structural integrity, electrical safety, and solar charging performance. Educational assessment was led by faculty and included observation of design reviews, evaluation of technical documentation, and analysis of student reflections. Students demonstrated improved understanding of renewable energy systems, interdisciplinary system integration, and engineering decision-making under real-world constraints involving cost, safety, space, and component availability.
The recovery and rebuilding of the golf cart at Sam Houston State University exemplifies how experiential, student-driven projects can translate classroom theory into applied renewable energy systems. The project strengthened student confidence in applying mechanical, electrical, and manufacturing principles to a fully integrated system while fostering awareness of environmental sustainability.

Future iterations will incorporate more formalized assessment tools, including pre- and post-project surveys, rubrics aligned with ABET student outcomes, and structured reflection instruments to quantitatively measure learning gains. Additionally, future technical enhancements may include hydrogen fuel cell integration, optimized solar tracking, and improved structural modeling to further advance system efficiency and educational value.

Overall, the project demonstrates that when students lead the engineering design, fabrication, and testing process under structured faculty mentorship, renewable energy initiatives can serve as both technically viable systems and high-impact educational experiences.

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