Development of Cal Poly's Hybrid AC/DC House

California Polytechnic State University, San Luis Obispo

Senior Design Project Report

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Abstract

The Hybrid House provides an example for what sustainable housing solutions could look like. It also functions as a potential solution to the current rural electrification issues many developing countries face. The use of a DC-DC MISO converter allows for combining multiple power sources into a single DC bus. The Hybrid House integrates the DC bus by employing the use of DC-DC converters for home use. This system may potentially improve the overall system efficiency by avoiding the losses associated with AC-DC converters. The use of the DC bus further leverages the Solar Panel renewable energy solution to become a more formidable power solution. This increased efficiency aligns with the overall goal of the Hybrid House which is to utilize mostly renewable energy in a home while still having the capability of integrating the grid power. Consequently, the Hybrid AC-DC House also offers an alternative solution for future sustainable house with improved reliability.

Chapter 1: Introduction

The majority of energy consumed globally comes from fossil fuels. The United Nations states on their climate actions page that fossil fuels are the largest contributor to global climate change [1]. This poses an issue to society as a whole since the use of electricity has given us access to incredibly useful technologies like the internet and communications systems. From NASA’s website about climate change the change itself is not what is alarming, but what is alarming is the rate of change [2]. NASA also states the heat trapping nature of carbon dioxide and provides Figure 1.1 to illustrate the stark difference in carbon dioxide levels. Regressing our current technology to slow or reverse the temperature increases could seem to work but looking to innovations in technology to solve the problem would most likely be best.

Figure 1.1 : Carbon Dioxide Levels taken from NASA

The innovations in technology would most likely have to come from generating energy in cleaner forms and using it more efficiently. This seems to be the best compromise for solving the climate change issue. This would employ the use of renewable energy generation like solar and wind. These sources of energy generation could help minimize the burden that is placed on the current energy generation and reduce the rate. A way to increase the efficiency of the new generation would be to find a way to utilize it without having to convert it to other forms.

When solar power is generated, it comes in the form of DC. The way it is broadly implemented today is by inverting this to AC and integrating it into the grid [3]. The power produced by the solar panels can then be utilized. Some devices also utilize DC so in order to use this power the AC must then be converted back to DC. This poses an issue since in order to use the solar panels they must be connected to the grid . This also means that if the grid is down the solar panels cannot be used meaning the energy being generated by the solar panels is not being used.

In order to be able to rely on renewable energy sources, it must first be efficiently used. Meaning that for the solar panels being able to remove power loss in the conversion from DC-AC since this accounts for 23-28% loss [4]-[6]. This would also remove the rectification of AC back to DC and thus remove the losses associated with this conversion. DC-DC converters would be much more efficient and reduce the losses.

The second thing that would be required before renewable energy could be utilized would be that it must also be reliable. Tying solar to the grid when you would want to use it to power the home does not make sense. Since if the grid goes down the power cannot be used. Which would mean connecting it to the home or building in a different way. This could be combined with energy storage in order to increase the reliability of such a system. The requirement of “[reliability] is taken into account to satisfy an efficient, coordinated and economical microgrid operation and ensure continuous availability of sufficient energy supply for local loads.”[7]

In some portions of the world people still do not have reliable access to electricity, “Globally, the number of people without access to electricity declined from 1.2 billion in 2010 to 759 million in 2019. Electrification through decentralized renewable-based solutions in particular gained momentum. The number of people connected to mini grids has more than doubled between 2010 and 2019, growing from 5 to 11 million people” [8]. Utilizing a renewable energy source like solar is one way to deliver more reliable power to homes. Making this generation local would be the most important part in order to prevent the reliability concern of the grid. Pairing this renewable power with energy storage would allow for a more reliable system for ensuring that power is available in a home regardless of if the sun is out or the AC from their power companies is up.

The implementation of this local DC power adds another issue that would have to be solved which is the conversion from DC-AC. This would require an inverter which would result in a loss in power from the efficiency. Instead of requiring this inversion and then further converting the voltage levels for multiple devices that utilize DC, building a system that only requires DC would increase efficiency and would thus mean the power produced through renewables would yield more usable power. DC-DC converters are more efficient than DC-AC converters. Utilizing the power created by renewable resources in an efficient manner would increase the reliability of the system. Being able to rely more on the DC side of the house is ideal for the design of the house.

Not all the devices people will utilize are DC so implementing a way to convert the DC that is produced and stored into AC is required. The Hybrid House is meant to facilitate use of electricity thus inverting the DC power supply would allow the ability to use AC devices. This will tap into the battery's DC power as well as the DC produced by the solar panel and invert it to supply the loads. Building a harmonious system like this would deliver a more reliable electrical home system where people could rely on the DC side to also run their AC for a reasonable amount of time. Powering the AC for shorter periods of time by relying on the DC would help to serve individuals who experience blackouts.

Developing countries are currently facing a rising demand for electrical power caused by various factors, including modern technologies and climate change. This trend is projected to continue as global temperatures are expected to increase, resulting in an inevitable surge in energy consumption. Unfortunately, the increase in energy usage places additional pressure on AC distribution grids that cannot cope with such a high demand.

This combination of factors is particularly concerning as an overloaded system can cause transmission lines and distribution elements to overheat [9]. To mitigate these risks, blackouts have become an increasingly popular strategy to alleviate the grid's stress. Additionally, recent developments have made DC more appealing due to cost and efficiency.

The Multiple Input Single Output (MISO) DC-DC converter is a power electronic device that allows multiple input sources to be connected to a single output load. This technology offers several advantages over traditional single input converters, including increased efficiency, improved power quality, and enhanced system reliability. In terms of sustainability, the MISO DC-DC converter can help to reduce energy waste and promote the use of renewable energy sources [10][11]. Such converters could be useful in programs designed to improve the quality of life for disadvantaged communities in remote areas that often require access to essential services such as health, education, and other community amenities.

Chapter 2: Background

Today, the majority of the distribution systems utilize AC. The main reason for this is the transformer since it allows for an easy way to step up and step down voltages. The adoption of AC was also popularized since there were no equivalent devices that could step up the DC voltage in order to reduce losses in electrical power distribution system. AC is used in the US, Europe and in countries with centralized distribution of power.

In recent years, the use of DC power transmission systems has become increasingly prevalent across nations and worldwide. As technology continues to advance, the demand for networking power products that can effectively utilize DC power is also on the rise. In order to maintain optimal energy conversion performance and power quality during the DC-AC conversion process it is crucial to insert power supplies and avoid any current distortion. The ongoing shift towards renewable energy sources is driving a significant transformation in electrical power systems globally, with numerous positive effects on power systems, the environment, and social engagement at a global level.

As climate change has become a larger issue, the United Nations(UN) has made it a goal to mitigate the effects. This was introduced in 2015 as Sustainable Development Goal(SDG) 7 which is from their website “Ensure access to affordable, reliable, sustainable and modern energy for all.”[8] The UN estimates that the number of people without electricity due to being situated in rural locations was about 733 million. One of the most important things that can be done to combat climate change is to provide reliable rural electrification. The UN also estimates that around 2.3 billion people still use unclean cooking fuels and technology. A method for providing electricity to these regions by implementing DC microgrids with dc generation, distribution and loads is much more efficient when compared to the losses sustained by conversions between AC and DC [12].

A topic that is brought up in the Scalable Solar Microgrids is that “The significant availability of electricity, even at very basic levels, is extremely crucial for human well-being and social resources development. On the contrary, the lack of electricity hampers basic human rights like access to clean water, health-care delivery, education facilities, and proper lighting, thereby enhancing poverty and significantly deteriorating the quality of life” [12].

Figure 2.1 Primary school in Pakistan, without access to electricity and basic education facilities.[12]

These topics for facilitating access to electricity in underserved regions are arguably more important than the issue of climate change. The lack of reliable electricity in these areas reduces the quality of life for individuals in these regions. The paper also highlights that the UN estimates that individuals in Sub-saharan Africa spend 40 billion hours annually just retrieving water. To put it differently, 40 billion hours are spent every year to collect water for drinking and sanitation purposes. Basic water needs are defined by the World Health Organization as “Drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip, including lining up and waiting” [13]. The WHO also estimates that at least 2 billion people worldwide lack safe drinking water at home and 1.2 billion of these do not have basic drinking water service. Contrasting this with a country like the United States where according to the US water alliance 2 million people do not have access to basic drinking water service the difference in percentage of population is very different. This highlights the hindrance that the lack of electricity plays in their lives since these hours could be spent increasing their social resources.

The team will be improving on the Hybrid AC/DC house that was worked on by Luis Rodriguez and Nicholas McAdams shown in Figure 2.2 [14]. The intention is to add a PCB printed MISO board and converters. This will improve efficiency, higher current output, and the ability to accept additional source inputs. By having the operation of a hybrid AC/DC system we can address how energy will give access to reliable and affordable electricity. A hybrid system will offer a solution to this problem by improving the efficiency of power systems and reducing energy waste. By facilitating integration of renewable energy sources, it can help to reduce dependence on costly and environmentally harmful fossil fuels, making energy more accessible and sustainable. Furthermore, the economic benefits will make them a viable option. The ability to use multiple input sources can provide greater flexibility in power systems, which can lead to cost savings in terms of equipment and installation. Additionally, the improved efficiency can result in lower energy costs over time, making them a more economical option for long-term use.

Figure 2.2: Hybrid AC/DC House

Chapter 3: Design Requirements

This iteration of the DC house expanded upon the previous design by implementing the MISO to increase power capability of the house. This maintains the goal of being powered mainly from renewable energy and using it in its most efficient form by preventing unnecessary conversion to AC [15]. For this reason a few choices were made in terms of the inputs for the MISO. Where many easy fixes could have been implemented the long term goal is to continue the main intent of the house.

3.1 System Design Block Diagrams

In Figure 3.1, the Level 0 Diagram is shown with the main components of the system displayed. There is renewable power present in the diagram shown by the solar panel. This provides the ability to not have to solely rely on the grid for power during the day. The battery is the storage element of the system and this allows access to electricity on days with less solar production or at nighttime. The MISO is what allows an increase in power by combining multiple inputs into one output with a high current capacity. This is then connected to the loads.

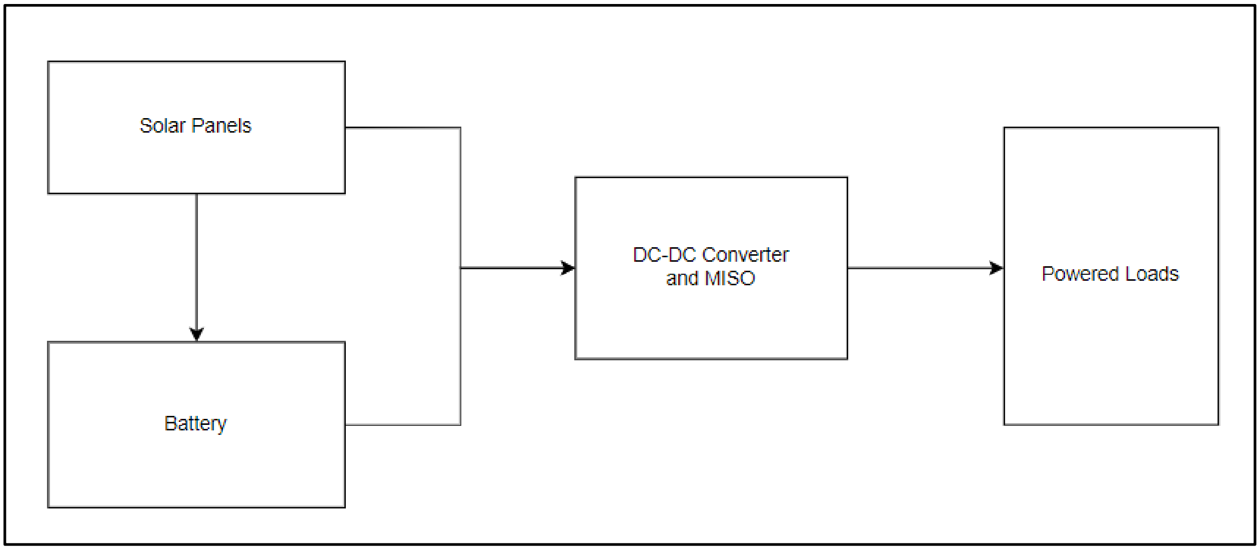

Figure 3.1 - Level 0 Block Diagram

In Figure 3.2, the image shows the level 1 block diagram of the system. There are more details regarding the way the system functions such as the use of a charge controller in order to charge the battery. The use of the charge controller allows the battery to be protected from overcharging. This diagram also introduces the AC-DC converter which is not a main portion of the DC portion of the house's operation. These dc sources are then input to the MISO which results in a 48V output at 12.5A. This then shows the use of a distribution panel with converters going from 48V to 12V and 48V to 24V.

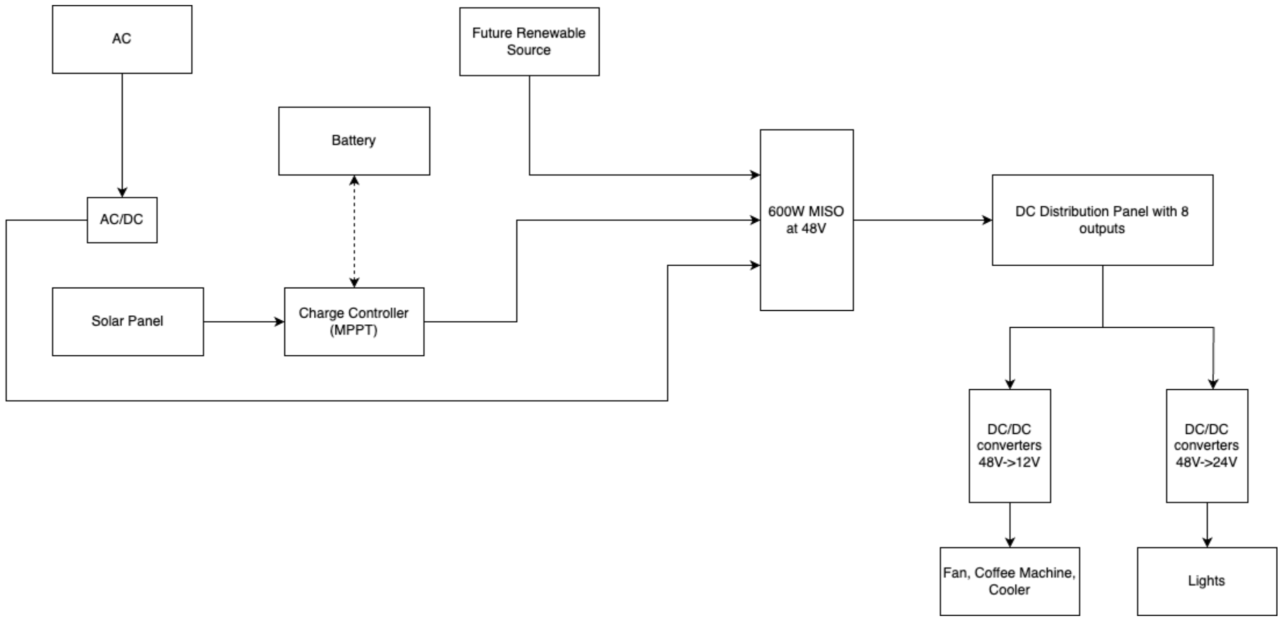

Figure 3.2 - Level 1 Block Diagram

Figure 3.3 shows a much more detailed overview of the previous image with the specifics of the operation of the MISO. The MISO has 200W modules that have their currents combined in order to achieve the 600W. This type of approach allows for a less expensive and easier way to handle repairs. This also increases the reliability of the system since each module has its own input and would still allow access to power at a reduced level if one of the boards were to break.

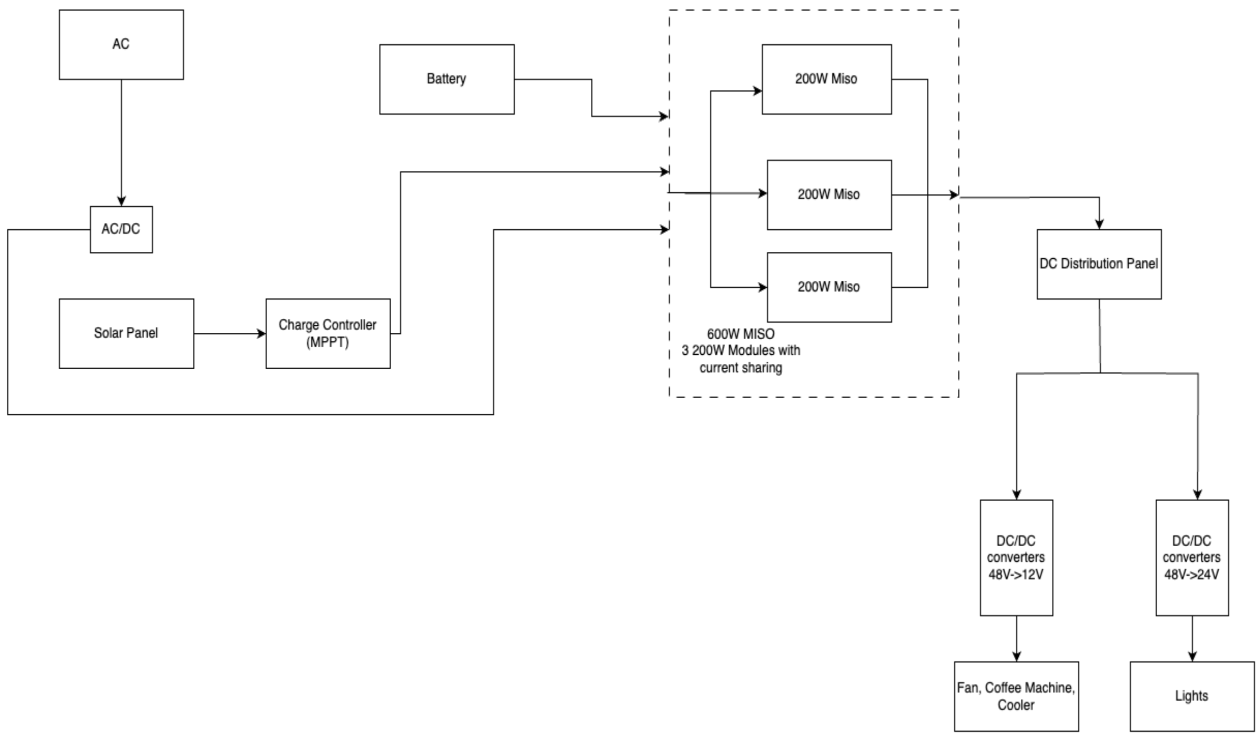

Figure 3.3 - Level 2 Block Diagram

3.2 Solar Panel

Supplying the DC power generation is a pre-installed solar panel rated at 18 V and 210 W. The solar panel will be the sole main source of DC power generation [14]. The Solar Panel is being reused since it serves the purpose of sustaining the current loads that the house has. This seems to be a limitation of the DC house in combination with the battery for when there are 600W of loads. Increasing the solar panel rated voltage to 30-36V would also allow for increasing the battery voltage rating. The increase in battery voltage would increase the power output of the Charge Controller and make the contributions from renewables to power the house much higher.

3.3 Charge Controller (MPPT)

The MPPT provides up to a 99% high tracking efficiency with a maximum of 98% peak conversion efficiency. These values yield superior IV efficiency characteristics. The manufacturer also states that the charge controller's conversion efficiency is higher where the solar panel voltage is higher than the battery voltage. This charge controller also provides room for future growth by changing the battery from a 12V to a 24V battery. This allows for accommodating a larger solar input in order to accommodate larger systems. As stated before, the conversion efficiency is higher when the panel voltage is higher than the battery voltage which would require a solar panel with higher voltage.

3.4 Energy Storage (Battery)

The battery is a 12V 1000Ah Lithium-Ion battery. This is being reused from a previous DC-house iteration but it serves the purpose of the current solar system. The voltage of the battery is lower than the voltage of the solar panel and therefore yields a more efficient energy conversion. The discharge characteristics of Lithium Iron Phosphate batteries is mostly flat which allow for a more consistent voltage. This is also a very safe battery to use, which is one of the main things that was considered. As stated before, the voltage rating of the battery seems to be one of the limiting factors of the house when speaking of the use of renewables as a power source. Increasing the battery rating from 12V to 24V would increase the system voltage of the charge controller and allow the charge controller to supply more power.

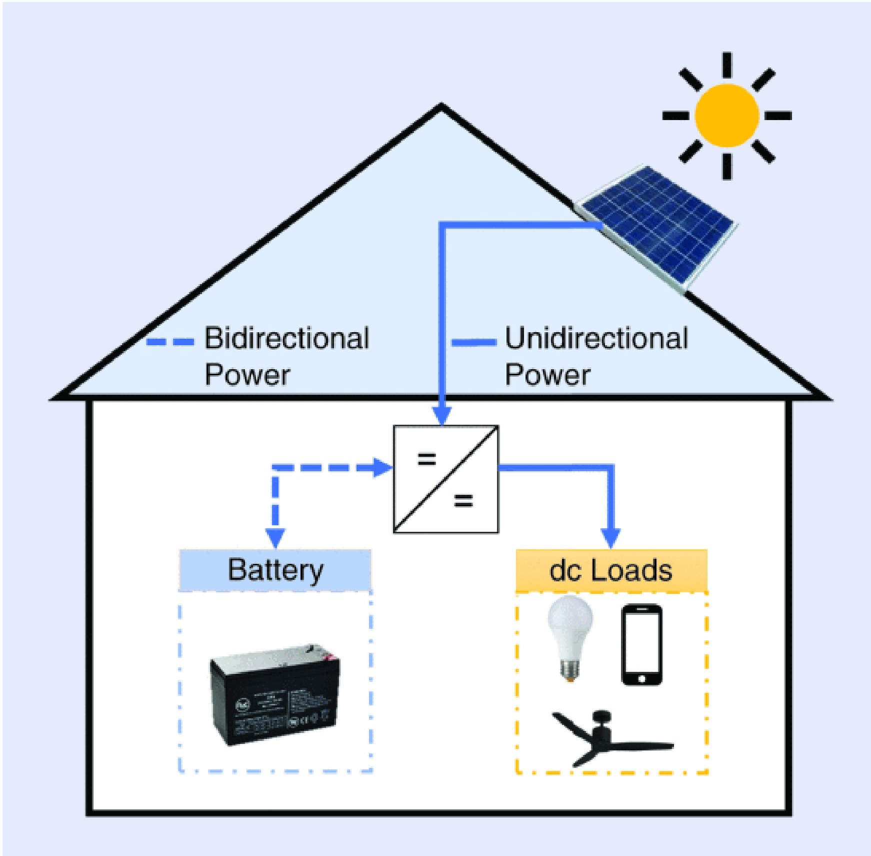

Figure 3.4 Operation of Battery and Solar Panel in DC house [11]

3.5 MISO

The MISO will allow for the combination of multiple power sources such as the 24V from the AC-DC converter as well as the battery and solar panel. The MISO has a nominal voltage 24V but can input 10V-60V [16]. The MISO has three modules that are each of 200W. These inputs will be combined and result in an output of 600W. The output of the MISO will be 48V since this was discovered to be the most efficient [17].

3.6 Converters

The converter type that was chosen was a quarter brick converter. This converter has the ability of taking in a voltage between 18V and 75V. This met the requirements of the expected output of the MISO being 48V. This converter also allowed for simplifying the design of the house. All 5 of the purchased converters are the same and therefore allows for easily moving a load around the house if necessary. The output of this converter will be at 12V since the majority of the loads are of 12V. This has the ability of delivering 100 Watts of power. This also had efficiency above 90% power we would be utilizing which in terms of the application of the DC house in rural communities would be most ideal to prevent wasting energy. The model that was chosen was the baseplate version. Another factor that was considered was size due to the conversion at the load as opposed to transmission of the power. This required a much smaller footprint for the converter.

3.7 Power Supply

The choice to add an AC/DC converter to power the house was seen as a necessity. Having the capability to utilize the grid to power some of the DC portion of the house is advantageous. This allows for being able to increase the power output of the house and would reduce the usage of battery storage on days that environmental factors prevent or greatly reduce the amount of energy produced. The power supply is only capable of delivering 150W, which is enough to supplement the renewables. This is a crucial decision in the house since increasing the power capability of the power supply would allow for easily reaching the 600W required for fully powering the MISO. This was decided against since the purpose of the project is to create a system that relies on renewables. Another choice for this choice was that the house does not consume 600W at its peak usage and this would be an unnecessary expenditure.

3.8 Wires

The wire gauge that was chosen for our application is the 12 AWG wire. The main reason for this is to minimize the voltage drop across each line. Ideally we want as close to 48V as possible. This being said there were a few considerations such as cost for the end application as well as the drop. Considering the size of the house we put a maximum of 30ft of distance and a tolerance of 3% into an online calculator. This yielded back the 12 AWG wire. 30ft will most likely be the largest distance between the converters and the distribution panel. By using a smaller gauge we could have yielded a better tolerance for the distance but a change from 12 to 10 in gauge size resulted in a doubling of cost for the materials.

Table 3.1 - Engineering Specifications Table

Engineering Specifications	Justification
Solar Panel 18V (200W)	Meets requirements for charging battery efficiently.
Charge controller	Protects the batteries and contributes to efficient charging
Battery 12V 100Ah	Meets requirements for time to be utilized at 250W. Meets requirement for charging efficiently from solar panel.
MISO 48V (600W)	The output of 48V seems to be most efficient for converting to other voltages, allows for current sharing and increased power capability of house
Converters 12V (100W)	These are smaller converters and allow for converting at the loads. This ends the

	distribution for the 12V system.
Power Supply 24V(150W)	Supplement the current PV system and future renewables.

Chapter 4: Design

The goal of the Spring 2023 DC house is to achieve a more efficient use of the solar power being created in the residential home. This will be done by implementing the MISO which will take in the DC power being created from solar panels and stored in the battery utilizing the charge controller and combining it to form higher power output. This system will also take in an input from an AC/DC converter which takes in AC from the grid and converts it to 24V. This will act as a supplement to the power being generated by the renewable side. Previously the power supply voltage and the solar panel voltage would be individually converted into 48V and the output would be combined in an or diode configuration. This meant that either the solar panel or the power supply would be supplying power to the house. In the current iteration these inputs from the charge controller and the power supply will be combined to form an output of 600W at 48V. The 48V will be input into a DC distribution panel where these will end up being bucked down from 48V to 24V and 12V. The 12V side is implemented such that the 12V loads would each have their own converter. Whereas the 24V portion will be shared between 24V loads as well as the lighting system in the house. As this project is constantly being continued we chose to focus on rewiring the house with the potential growth in the solar panel and battery setup. Since at the moment this is the limiting factor of the home due to the charge controller having a maximum load current of 20A. The 20A at 12V can supply a maximum of 240W but a system with a battery of 24V and a solar panel between 30-36V would be able to supply the MISO with a maximum of 480W.

4.1 Solar Panel

The STP210-18 solar panel is the current solar panel being used in the house and will be the one used during this iteration of the project. The Solar Panel has a nominal voltage of 18V. Having a nominal voltage higher than the voltage of the battery increases the efficiency of the charge controller which is why it was determined to still serve the purpose. The solar panel is shown in Figure 4.1. The Solar Panel is also capable of producing up to 210W which is less than the maximum input power the charge controller can handle (400W with the 12V battery). An improvement that could be made in the future is to increase the voltage for the solar panel to sustain a 24V battery. This would increase the power capability of the charge controller.

Figure 4.1: STP210-18

4.2 Battery

The battery is utilized to store produced energy while the solar panel is not being used. This can then be used later on at night or if the sun is not shining through. The characteristics of the battery match with the current implementation of the solar panel system. The nominal voltage of the solar panels is 18V which would require a battery below 18V in order to properly function and to provide the most efficient system. Due to this the voltage of the battery was required to be 12V due to the restriction of the nominal voltage of the solar panel. The battery is 100Ah and can supply 1200Wh for the previous version of the project a 250W for 4 hour requirement was made. Previously there was a TV but it is no longer in the house; there has been an addition of a 50.4W cooler. This in combination with a fan and the lights still falls below the 1000Wh requirement from the previous group. An improvement that could be made for the future is increasing the battery size to improve charge controller power capability.

Figure 4.2: 12V 100Ah battery

4.3 MISO

The implementation of the 600W MISO into the house was the main portion of the project. This is made up of three 200W modules shown in Figure 4.3 that are combined to form a 600W output at 48V. The fully constructed MISO board is shown in Figure 4.3. 48V was chosen for the output voltage due to previous findings showing the efficiency was best with this. When the MISO is fully powered by the inputs, it increases the power capacity of the house substantially compared to the previous iteration.

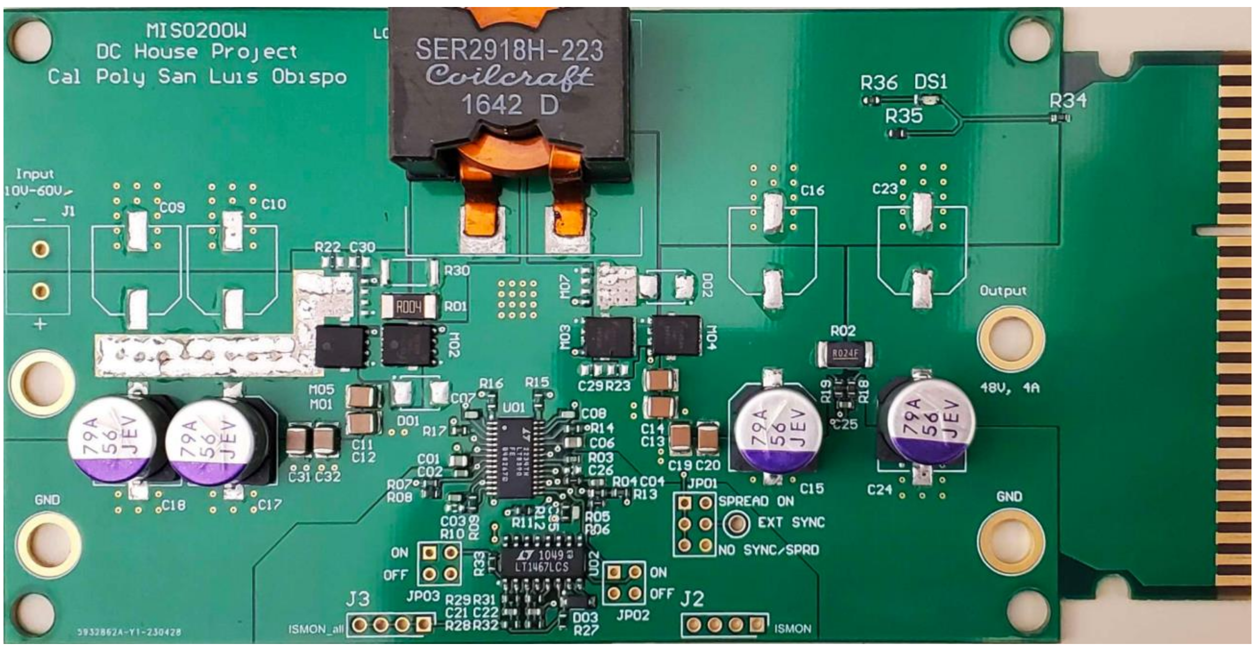

Figure 4.3: 200W MISO module

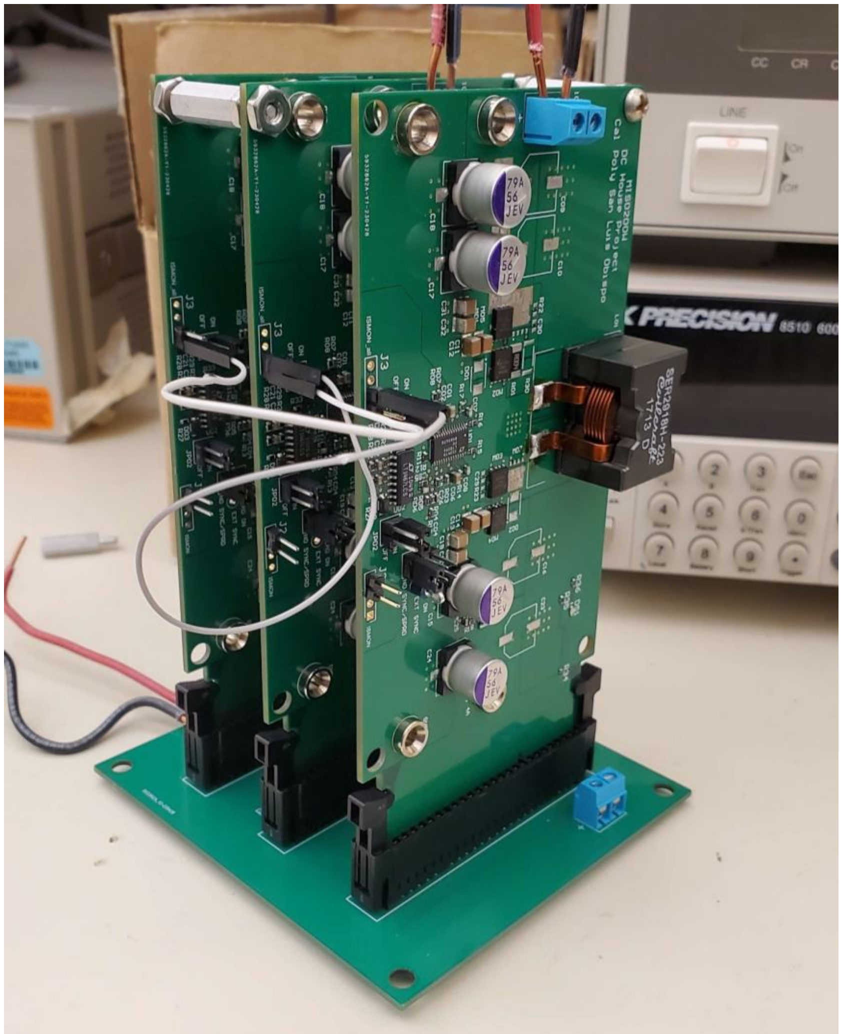

Figure 4.4: Fully Constructed MISO

4.4 Converters

12V DC-DC converters were purchased in order to convert the output of the MISO to a voltage that loads would utilize. Previously the method that was used to implement 12V loads was converting the 48V for the whole house and then distributing that. This method was determined to be less favorable than utilizing individual 12V converters for each load. The current iteration now converts 48V to 12V at the load. Since each converter will only be converting for each load a smaller footprint for the converters than the DIN-rail type that was previously used. This led to the dimensions of the converter being very important and led to the choice of using a quarter brick converter. The quarter brick converter is high density meaning that for its footprint it can deliver high amounts of power. The model chosen was the PRQ100W-Q48-S12-B-D which can take in a voltage between 18V and 75V shown in Figure 4.4. This will also output 12V at a maximum of 100W. Upon completing the application circuit the length of the converter is larger but due to the implementation with prototype boards the size was not fully optimized.

Figure 4.5: PRQ100W-Q48-S12-B-D converter

Chapter 5 Hardware Test and Results:

5.1 Charge Controller

The model of the charge controller and the housing has remained the same from the previous iteration of DC house. The housing requirements needed have not changed. The clear cover allows for easily seeing whether or not the solar panel is connected and if power is being supplied by the charge controller. The size of the housing also fits well into the current setup and provides an easy way to connect the output of the charge controller to the MISO input.

Figure 5.1 Renogy Charge Controller

5.2 MISO

The MISO shown in Figure 5.2 is placed to the right of the converters on the rail and the charge controller housing. This easily lets the inputs to the modules be wired and does not disturb the overall appearance of the house. The location above the DC distribution panel was also very important as it would allow for an easier flow of wires to the input side of this panel.

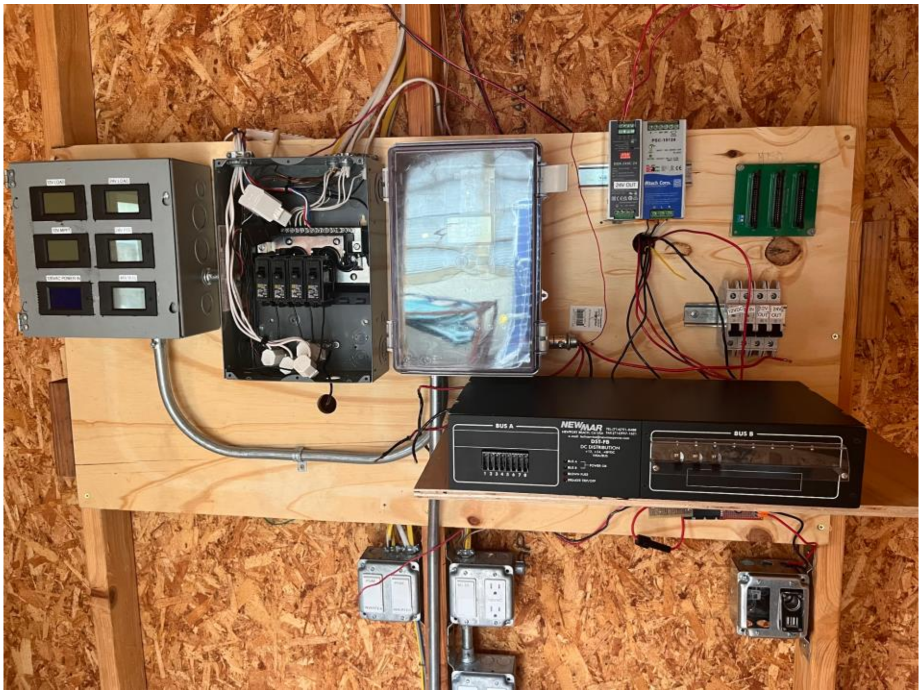

Figure 5.2 MISO Placement

5.3 Distribution Panel

The distribution panel shown in Figure 5.3 was utilized in order to simplify the wiring of the house. The MISO output of 48V serves as the input into the distribution panel where all outputs are also at 48V. The distribution panel has screws on the back portion and 8 outputs. This allows for easily scaling the devices that utilize the 48V in the future since there are multiple outputs from the panel. The distribution panel implements protection in the form of breakers built into it. The shelf was chosen over closed enclosures in order to prevent overheating. The distribution panel has openings on the side which suggest it needs proper air flow in order to stay cool.

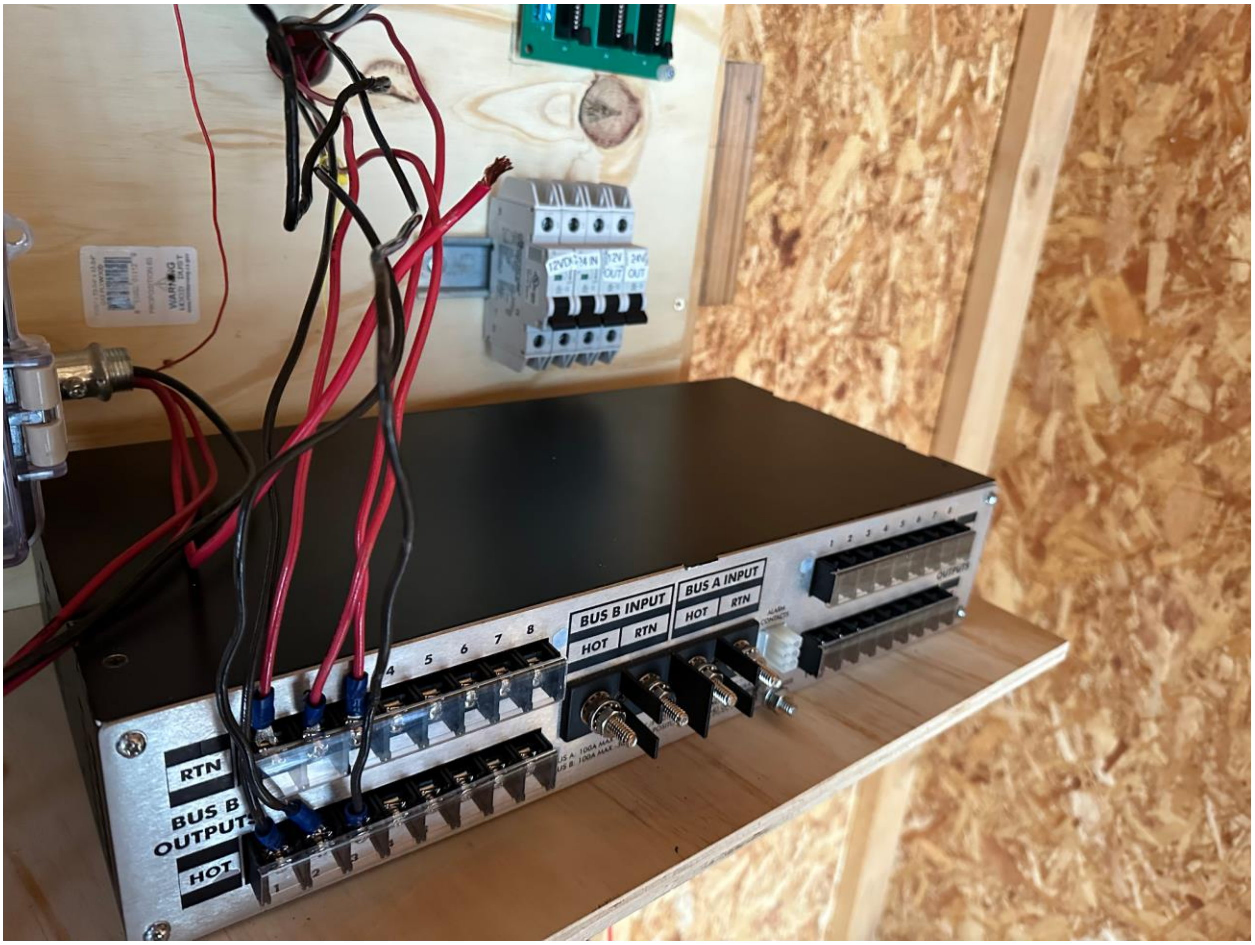

Figure 5.3 Distribution Panel on shelf in the house

5.4 DC to DC Converters

The DC-DC converters were designed to convert and regulate DC voltage levels. The DC wall outlets provide direct current (DC) power supply. When connecting a DC-DC converter to a DC wall outlet, the objective is to convert the available DC voltage to a different voltage for a specific application. As seen in Figure 5.4

Figure 5.4 Wired DC to DC converter

This DC-DC converter is positioned at the top right hand of the house, with enough space should any modification be needed. The converter has the capability to handle 48V input when utilizing 48V. This requires a polarity reversal at the input. Inverting the polarity enables compatibility with other devices since many require a specific polarity to function properly. The converter will provide stable an output voltage even when the input voltage fluctuates. This will ensure that the load receives a consistent and dependable power supply and protects the unit.

Figure 5.5 12-Volt DC system Dual USB Power Outlet and 15A - 125V Heavy Duty

For this specific unit Figure 5.5 we have both DC (Direct Current) and AC (Alternating Current) wall outlets. This wall outlet can provide flexibility and accommodate a wide range of devices and appliances. DC power poses a lower risk of electrical shock compared to AC power. In certain scenarios having DC outlets can enhance electrical safety, especially when powering low-voltage devices where the risk of electric shock needs to be minimized.

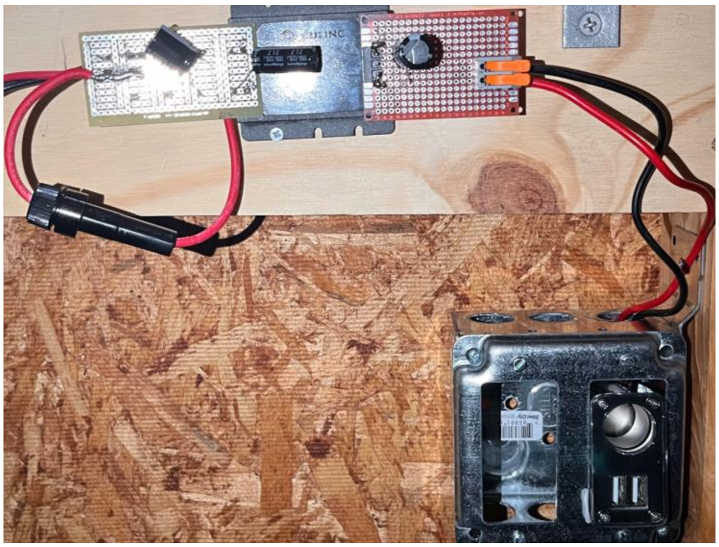

Figure 5.6 12-Volt DC system Dual USB Power Outlet

This DC-DC converter is located below the DC distribution panel, with enough space should any modification be needed.

Figure 5.7 12-Volt DC system Dual USB Power Outlet and 15A - 125V Heavy Duty

This DC-DC converter is located in the upper left hand side of the house.

5.5 DC outputs

The MISO will integrate multiple DC power sources, such as solar panels and batteries in order to provide electricity to various devices. As shown in Figure 5.9 it will be connected to the back of the NEWMAR DC Distribution. Figure 5.8 will be located on the bottom right side of the charge controller. The NEWMAR DC Distribution has two sides. In Figure 5.10 the front of the device you have BUS A, this side is able to hold up to 8 fuses and BUS B has 3 switches. BUS A was not picked because fuses require replacement when they blow or fail, switches offer the convenience of immediate resetting. If a fault occurs you can switch off the power and turn it back on once the issue is resolved. This eliminates the need for replacing fuses saving time and cost. The side that was picked was BUS B OUTPUT ports 1-3. For RTN ports 1-3 were picked and for HOT ports 1-3 were picked as shown in Figure 5.9. The reason this was decided was to have precise control of the output and it has a clear protective toggle guard which is used to prevent accidental switching. Having control over the switches allows for the immediate shutdown of power without compromising the safety of other parts of the system.

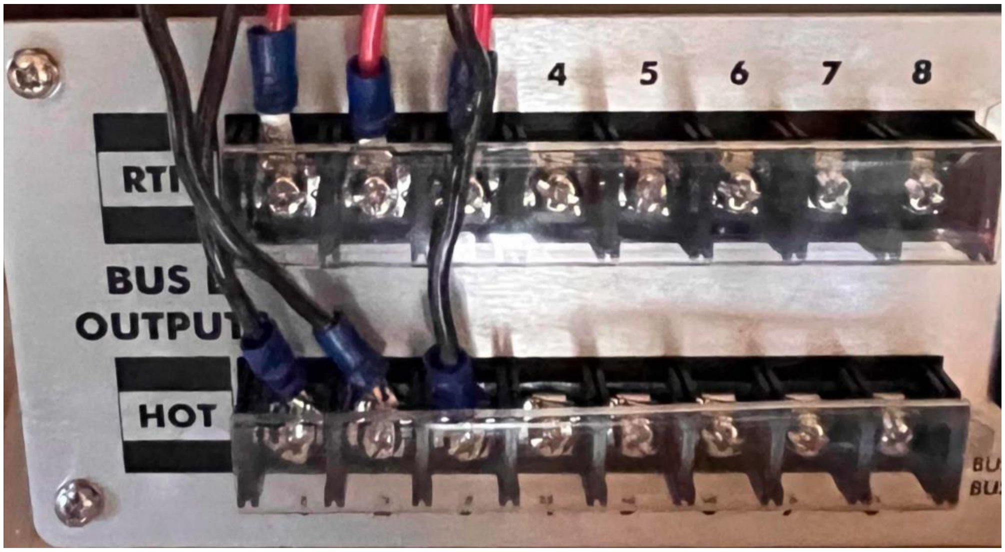

Figure 5.8 Closer picture of the Back of NEWMAR DC Distribution.

Figure 5.9 Back of NEWMAR DC Distribution.

By utilizing DC output one can have potential advantages such as increased energy efficiency, reduced power conversion losses, and improved integration of renewable energy sources. For this project the DC outputs are going to be wired by a 12 AWG Red and 12

AWG Black wire. The PSC will be wired to one of 3 breakers, this breaker will be connected to one of the 200W modules for the 600W MISO as shown in Figure 5.9.

Figure 5.10 Front of NEWMAR DC Distribution.

Chapter 6 Conclusion:

The DC house is aimed at providing a sustainable alternative for electrification of rural areas. The sustainability of the house is displayed by the use of renewable energy as the main power source of the house. By integrating the use of the solar power generated by the photovoltaic system in its native DC form as opposed to AC, there is an initial savings of around 23-28% due to the loss of converting to AC [4]. This iteration improved the power capability of the DC portion of the house by utilizing the MISO. At maximum output the MISO will be able to supply 600W of power to the house. This 600W design would integrate into a very usable system since this allows for utilizing multiple DC loads at the same time. The MISO system exhibits a very modular design that promotes the reliability of the house and user experience. If one of the 200W MISO boards were to break, the two remaining boards could still support 400W output. The use of multiple DC-DC converters for the common 12V wall plugs also prevent the inability to use 12V devices if the outlets were to go down. These are also terminal block plugs that have switches as opposed to the terminal block plugs that have screws which make changing them out much easier. These output channels provide the ease of expanding the system in the future.

Although many improvements and redesigns were made to the previous Hybrid House project there are still more to be done. As stated earlier in the document the current system does not support the full 600W of the MISO which is not an issue since the loads do not consume 600W at their peak. In the future this will be required and the solution must involve additional renewables. The current photovoltaic system limits it from supplying the remaining power. This can be fixed by changing the battery and solar panel but other options should be explored in order to diversify the renewable energy generation. At the moment the monitoring of the AC portion is done through an app with sensors that provides a convenient way to visualize usage and the function of the house. The DC portion is still utilizing the shunt sensors and there were no options found on the market to conduct this. Charging the battery can be improved to charge from AC and the Solar Panel. This would benefit the system by simulating times where the grid would be functioning but the photovoltaic system would produce insufficient voltage and current. The method for doing this would be to look for existing chargers and modify the current system to select between the MPPT charge controller and the AC charger.

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Appendix A: Analysis of Senior Project Design

Summary of Functional Design Requirements:

The Hybrid House is aimed at addressing the issue of providing a solution to rural electrification. The design does this by implementing a sustainable and environmentally conscious design. The goal of the house is to rely mainly on renewable energy sources such as solar to provide and store energy. The house takes the energy from renewables and some supplemented from the grid and creates a DC bus that is utilized by the DC portion of the house. This bus voltage is converted to whatever the load of interest would need from 12V or 24V. Utilizing the renewables in this way enables a more efficient use of the energy and avoids the higher loss and unnecessary conversion to AC. The house does however have an AC portion which would allow for using the typical AC devices in a home.

Primary Constraints:

The DC house as a whole is a relatively novel idea. The majority of the work done with DC systems takes a look at the microgrid level and not at a residential level. Previous DC house projects were the main area where guidance was taken from. The implementation of another group's project into the house is what mainly impacted the approach. The other group was in charge of building a DC-DC MISO which is what creates the bus voltage of the house. Interfacing with the MISO group was required before any decisions regarding the wiring of the DC outlets was done since the size of the MISO would determine its placement in the home.

A specification of not converting to 12V for the whole house with 1 converter and distributing it also played a large part in how the wiring was conducted. It required utilizing a DC distribution in order to easily access the 48V bus. This also required wires of this 48V going out to the outlets where individual DC-DC converters were placed. Since converting at the load was a requirement we had to find small converters. This required lots of time in searching for a converter that met the size requirements as well as construction of application circuits for the converters.

Economic:

What economic impacts result?

Upon implementing Hybrid House would have an economic impact in terms of natural capital. The House's main aim is to utilize renewables as the main power source; this would reduce the utilization of nonrenewable resources and reduce the emissions related to them. Hybrid House would also have an effect on financial capital since this would initially have a cost like any other home but long term would reduce if not eliminate the money spent by individuals to power their home in rural areas.

When and where do costs and benefits accrue throughout the project's lifecycle?

The house is aimed at more efficiently utilizing the power created by renewable energy sources. The solar power in the house is utilized in its native DC form and is not converted into AC which saves a tremendous amount of power. By doing this the power created could power more things and would result in less need of the grid.

What inputs does the experiment require? How much does the project cost? Who pays?

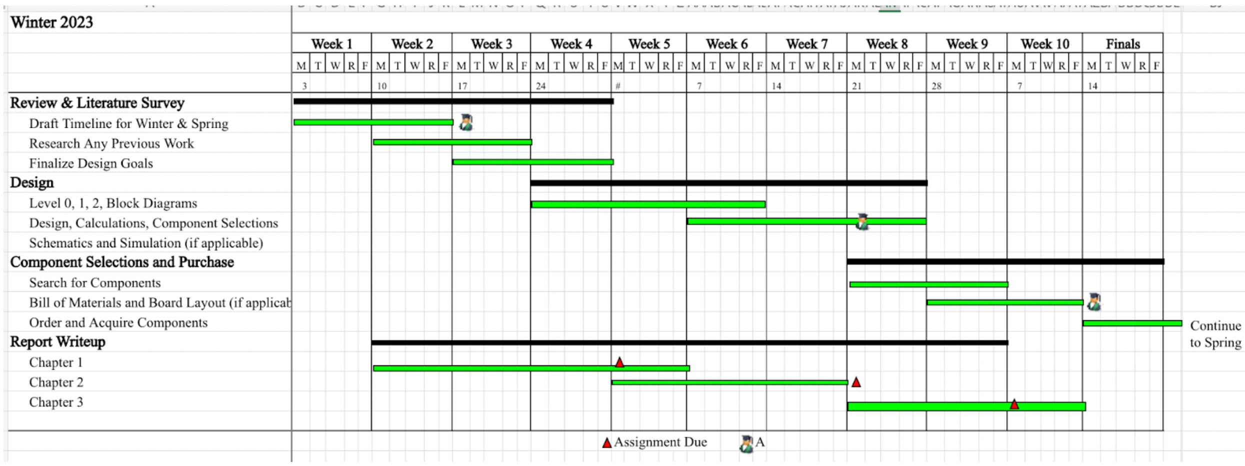
Estimates from previous projects show the total house experiment including the shed being around $20,000. In the case of our specific project the converters cost around $580 to acquire and then fully construct. The wires that were used cost around $70. Although not a purchase of our own the home implements another project which totaled $AAA.AA?. Since this is a project that can be used for research Cal Poly should pay.

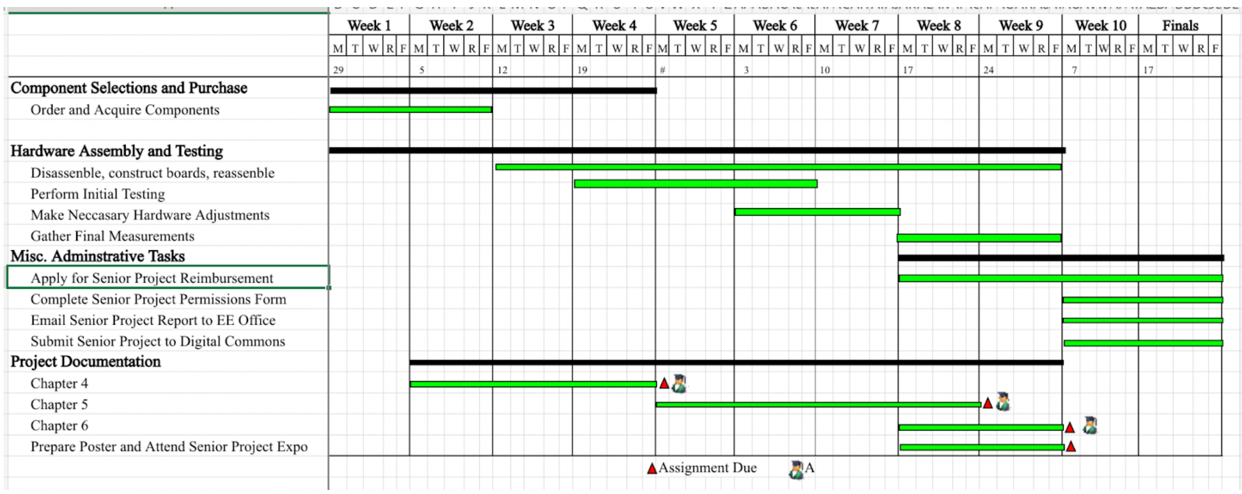
How much does the project earn? Who profits?

At the moment I do not believe the house would earn a lot. There are still areas that must be improved in order to facilitate its adoption by the market. Since this is a Cal Poly project I am sure the school would be the main group that profits from this.

Timing

This project took around 4 months to fully plan and construct. In the future this portion in a standardized house would most likely take less than 2 weeks. The house as a whole should last 30 years. There are failure points in the MISO board as well as the dc-dc converters that may not last as long. A proper failure analysis should be conducted for these but the main importance was that they would be easily replaceable if broken.





If manufactured on a Commercial Basis:

In 2021 514,000 residential PV systems were installed. Although it would be extremely hopeful to say that this is the market I don’t think that this is the case. Hybrid House at the moment is aimed at providing an efficient way to utilize power in the standardized home. This specific project most likely has a much smaller market share than the 514,000 shown above. I would say less than 0.5% of those who purchased residential solar would be interested in purchasing hybrid houses. The reason being is that the whole house is the product not just the system. If the system were to be sold instead it would make the most sense. It would most likely have a market share of 1-2% of the 514,000 since the customers would have to be informed as well as care enough to implement such a system. This would leave around 5,140 customers that could purchase a system at $8,000. This would result in $41.2 million in revenue most likely from a manufacturing cost perspective this would be between $4000-5000. This would yield a profit of around $15.4 million. Ideally this would not cost the user anything to operate since it would be getting energy from renewables and storing it for future use in the home.

Environmental:

The environmental impact of the house is that it uses resources such as petroleum to manufacture multiple portions due to the plastics. Copper is also utilized in order to wire the home. The home is also constructed from wood. Even though the home requires fossil fuels to be constructed it is aimed at reducing the long term use of fossil fuels as the main energy source by relying more heavily on renewables. The battery in the home uses lithium which must be mined and this seems to be a very water intensive process.

Manufacturability:

Manufacturing components and systems associated with the implementation of a DC house with a more efficient use can pose several issues and challenges. Finding reliable supplies for the necessary components, such as solar panels, batteries, charge controllers, and DC to DC converters can be a challenge. Ensuring the quality and compatibility of these components is crucial for the overall system performance. Implementing a control mechanism to regulate power flow requires precision manufacturing. Manufacturing components and systems that are reliable and safe for the long-term is important. Ensuring proper protection against electrical faults is crucial.

Sustainability:

The integration of multiple components, such as solar panels, batteries, charge controllers can make maintenance challenging due to the complexity of the system. Over time, individual components will degrade and reach the end of their lifespan which will require replacement. Managing component replacement and ensuring the availability of compatible replacements can be a challenge. The project is going to be implementing a DC house system with solar power that helps reduce reliance on fossil fuels and promotes the use of clean, renewable energy. This contributes to reducing greenhouse gas emissions. A upgrade that would improve the design of the project would be in upgrading the battery storage system and having it utilize a more efficient and higher capacity battery that can enhance energy storage. Issues associated with upgrading the design would be cost and affordability. Upgrades may come at an expense making it hard for homeowners to adopt this technology. Not only that but upgrading components or adding new features to an existing system may require ensuring compatibility with the current setup which can be challenging.

Ethical:

The project’s design and manufacture should consider fair and responsible allocation of resources. This includes assessing the environmental and social impacts associated with the extraction of raw materials for manufacturing the components. Ethical considerations also involve ensuring that the project does not contribute to resource depletion. Misuse of the project can violate safety, compromise performance. Manufacturers should incorporate safeguards to prevent these types of modifications and provide clear guidelines to discourage improper use.

Health and Safety:

The design, manufacture and use of the project can involve several health and safety concerns. Working with electricity poses risks. During the design and manufacture phase, ensuring proper insulation, grounding, and protection against electrical faults is essential. Users should be educated about electrical safety practices, such as avoiding contact with live wires and following proper procedure for maintenance and troubleshooting.

Social and Political:

The social and political aspects associated with the design, manufacture and use of the project are as follows.

- Environmental benefits: The project focus on renewable energy contributes to mitigating climate change, reducing air pollution and promoting sustainable practices. This benefits society as a whole by creating a cleaner and healthier environment.
- Energy Accessibility: The project can impact communities that have limited access to reliable electricity. By providing an alternative energy solution it can improve energy access, particularly in underprivileged communities.

Who are the direct and indirect stakeholders?

The direct stakeholders would be homeowners. Those who install and use the system directly benefit from reduced reliance on the grid, cost savings on energy bills. Manufacturers involved in designing and supplying the components and systems directly benefit from the demand and growth. The indirect stakeholders would be the utility companies. The integration of this technology may disrupt traditional utility business models. This will cause utility companies to adapt and transition towards a more decentralized energy.

How does the project benefit or harm various stakeholders ?

Benefits to stakeholders would be economical opportunities. The project can create job opportunities in renewable energy industries, supporting local economies and fostering sustainable growth. Reducing dependence on fossil fuels. Potential harm to stakeholders would be the initial cost. The upfront of implementing the project may pose a financial barrier for some homeowners, potentially creating inequalities to renewable energy.

Pay equally ? Does the project create any inequities ?

The project can create some inequities related to pay if there are differences in the cost and accessibility for implementing the system. The initial cost associated with installing the project may post challenges for individuals with limited financial resources. This could result in inequities where those with higher economic power are more able to afford and benefit from the project, while those with lower income may face barriers.

Development:

This project builds upon previous projects, specifically upgrading of the Hybrid AC/DC House: The Road to a Sustainable Future. This was found by having access to Digital Commons at Cal Poly database. In this project we had the combination of DC to DC converters and the MISO systems which brought together multiple DC power sources, such as solar panels and batteries, to provide electricity to various devices. This integration offers several advantages, including increased energy efficiency, reduced power conversion losses and improved integration of renewable energy sources. By efficiently converting and distributing power within the systems, the DC to DC converter optimizes the utilization of renewable energy, minimizing energy waste and promoting sustainability.