SolGo ARV Electrical System

By

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Project Design Document

SAC Undergraduate Research Program
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ALAMO COLLEGES

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Contents

Introduction

Since the first gasoline-powered automobile was invented in Germany in the late nineteenth century, the consumption of gasoline and petrol has grown exponentially. Subsequently, air pollution, from gas emissions of those fuels, has also been increasing.

Alternative energy sources, such as solar power, offer an environmentally friendly option in place of fossil fuels. These alternative energy sources help reduce the amount of harmful pollutants and greenhouse gases emitted by the burning of gasoline and other fossil fuels in vehicles. They are also part of a solution for the inevitable fossil fuel shortages in the future. And finally, alternative energy sources might reduce the cost of fuel for vehicles as they are renewable sources and always available. To use alternative energy sources in place of fossil fuels is to look for a better future of the environment.

The Team of SolGo ARV (Alternative Resources Vehicle) Electric, in this SAC Undergraduate Research Program of 2015, has set two primary goals. First, our team focuses principally on building a durable solar electric vehicle based on a golf/utility cart frame. The car will use electricity from the batteries to power the motor of the car with solar energy as a source of energy to charge the batteries. Second, the car will be used to illustrate the scientific and engineering principles of alternatively fueled cars to evoke SAC student's, children's, and other's curiosity and interest in alternative energy sources and science, technology, engineering and math careers (STEM). The SAC Mathematics Engineering Science Achievement (MESA) Center will use the SolGo ARV to showcase STEM at various events on and off campus.

Background

Previous SAC Undergraduate Research Program (SURP) participants have provided advantageous information and resources, which we can incorporate into our own project. Prior SURP teams have used photovoltaic (PV) panels in their projects to find ways to improve their maximum efficiency and Team Heavy's (previous SURP participant in 2013) research demonstrated the performance of a battery powering an electric motor running at different speeds when either connected or disconnected from a PV panel. This information can be useful to our SURP project since we will have some background data on how to make the battery packs the most efficient. In addition, we can use the previously purchased PV panels for our use and will allow us to use our funds towards the purchase of other vital components.

SolGo ARV consists of two teams, the electrical team and the mechanical team. The electrical team deals with all the electrical devices and how they are going to function together. The mechanical team works to provide the best frame possible, body, suspension, and mechanical components for the electric cart. We are collaborating with each other by attempting to figure out how we will mount the electrical elements onto the frame of the vehicle. This is being carried out with measurements, safety, and accessibility in mind.

Requirements for the SolGo ARV were to accommodate seating for two people, have the ability to maneuver in reverse, provide storage compartments for common school handouts, personal items, and include appropriate safety items (lights, brakes, horn, seat belts).

Alternatives Considered

There are 5 major components to a solar-electric vehicle.

- Photovoltaic Panels - Converts sunlight into electrical energy (Also called solar panels or solar modules)
- Charge Controller - Regulates voltage and current applied to the batteries produced by PV array.
- Battery Pack - Storage source for power being produced by PV array
- Motor Controller - Regulates how the motor will run through the controlling of current and voltage.
- Motor - Converts electrical energy into mechanical energy

Motor

Because we are continuing the work of the Team Heavy *Electrical Subsystem for Solar Panel Electric Cart* report, we will be using their suggestion for motor and motor controller which is the ME0909 and AXE4834 respectively. The ME0909 motor fits our specifications perfectly. We are using a Club Car Turf 2 utility cart as our frame. The original motor for the Turf 2 is a 3.7 horsepower shunt wound motor. The ME0909 can reach up to 4 horsepower continuously at 48VDC (see Appendix C).

Photovoltaic Panels

We will be reusing the solar panels from previous SURP projects which are Yingli YL235P-29B's (see Appendix F). That leaves our team with batteries and a charge controller to consider.

Batteries

The main limitation of a purely solar powered vehicle is that the amount of electricity is dictated by the availability of sunlight. If the sun is shaded, or if it is in the evening time, the car will not be able to run. The way we get around this problem is by using a battery pack to store the energy produced by the solar panels, when sunlight *is* available, for later utilization. We had three options as for which type of battery to use.

- Lithium Iron Phosphate ($LiFePO_4$)
- Lithium Polymer (LiPo)
- Absorbed Glass Mat (AGM)

Lithium Iron Phosphate batteries

Lithium Iron Phosphate batteries ($LiFePO_4$) are a type of lithium ion battery. They are efficient and very safe. One of the biggest advantages is the fact that they have a constant discharge voltage. That means that if the the battery is rated for 3.2V, it will stay close to that voltage as it discharges. This is important as the motor will be able to operate at an optimum torque throughout a discharge cycle of the battery.

The $LiFePO_2$ battery is a chemically stable battery. Regardless if the battery is charged or depleted, the bonds between the Fe-P-O ions remain strong. Oxygen (O_2) molecules are unlikely to disassociate and 'leak' out, reducing the risk of ignition in the case of mishandling.

The biggest drawback lies in the charging. Because no standard charge controllers offer charge profiles for any lithium based battery, we would be required to buy an expensive programmable charge controller.

Lithium Polymer

Lithium polymer (LiPo) batteries are another type of lithium ion battery. The polymer denomination comes from the soft and lightweight polymer encasing. This type of battery is typically used in cellphones and laptops.

As with all lithium ion based batteries, LiPo batteries are susceptible to overcharge, overheating, and electrolyte leakage. When a battery is overheated or overcharged, the liquid based electrolyte undergoes vaporization. Because the battery has a soft case it will expand and possibly explode. In order to use LiPo batteries safely, the solar electric car would need to have a battery regulation system which we would purchase or make ourselves. That requires either time or money that could be better spent elsewhere.

LiPo batteries also require specific charge stages just like $LiFePO_4$ so the same drawbacks in that regard apply to LiPo as well.

Deep Cycle Absorbed Glass Mat

Absorbed glass mat (AGM) batteries are a special type of sealed lead acid battery. The acid electrolyte is absorbed by fiberglass making the battery spill-proof. This kind of configuration also allows for greater resistance to vibration and shock as the mats and metal plates are tightly packed within the battery.

The biggest advantage to AGMs is that they are very safe. In addition to resistance to vibration and being spill-proof, AGM batteries are *recombinant* batteries which means that any released O_2 and H^+ ions recombine within the the cell itself so there are no concerns with fumes even when used in high temperature environments. This also means that we don't have to equalize the electrolyte levels periodically, which is typical for standard flooded lead acid batteries. AGMs require less maintenance all around.

When it comes to charging AGM batteries with solar panels, AGM batteries are the most favorable. Sealed lead acid batteries (AGM included) are the industry standard for off-grid solar electric energy storage. This means we would not need a custom programmable charge controller, but can use a lower cost standard off-the-shelf unit.

Conclusion

With a good life cycle, safe chemical configuration, and easy interface with solar charging, our team selected absorbed glass mat (AGM) battery for our vehicle. The model of battery we chose is the Power Patrol 1155 12 volt battery. We will have 4 in series, producing a 48V battery pack. The reason is that 48V is the optimum voltage rating for our electric motor.

Charge Controller

When charging a battery bank by means of photovoltaic panels it is important to include a charge controller to regulate the panel voltage and current provided to the batteries. The reason is that if the panels were directly connected to batteries, the varying voltage and current could damage the battery cells by overcharging or undercharging. When it comes to selecting a controller we have two types to choose from.

- Maximum Power Point Tracking (MPPT)
- Pulse Width Modulation (PWM)

Maximum Power Point Tracker (MPPT)

A MPPT, is a type of DC-DC converter that optimizes the voltage coming out of the solar panels to match the voltage of the battery pack. The way it works is quite simple. The controller takes the DC input from the panel and converts it to a high frequency AC (up to 80 kHz).
The AC is then rectified back to DC, at the battery pack voltage, optimizing the charge going to the battery pack. Here is a table of popular models of MPPTs (fig. 2).

MPPT Charge Controllers

Company	Model	Price
Outback	FLEXmax 80	$554.00
Midnite	Classic Lite 150	$540.00
Morningstar	Tristar 60	$499.00

**Prices taken from Wholesale Solar*
fig. 1

Pulse Width Modulation (PWM)

There is a second method of solar charging called PWM. Instead of a steady output from the charge controller, it sends out a series of short charging pulses to the battery - essentially working as a very rapid "on-off" switch. The controller constantly checks the charge of the battery to determine the frequency and wavelength of the pulses in a fully charged battery with no load, it may just "tick" every few seconds and send a short charging pulse to the battery. In a discharged battery, the pulses would be very long and almost continuous. The controller constantly checks the state of charge the battery between pulses and adjusts itself each time. Here is a table of popular PWM models (fig. 2).

PWM Charge controllers

Company	Model	Price
Schneider Electric	Xantrex C-40	$110.00
Morningstar	Prostar PS-15M	$190.00

**Prices taken from Wholesale Solar*
fig. 2

Conclusion

With consideration to simplicity and price, our team selected pulse width modulation as our charge controller method. The model we selected is a Prostar PS-15M charge controller from Morningstar as it proved to be the most cost effective (See Appendix D).

Proposed Design

Following the suggestions of Team Heavy as well as our analysis detailed previously, the electrical configuration for the SolGo ARV will be the following:

- One 48V, 4 horsepower permanent magnet motor
- One 48V, 300A motor controller
- Four 12V, 35Ah AGM batteries
- Two 235W Polycrystalline solar panels
- One 48V, 15A PWM charge controller

Operation

The operation of the solar electric car works as follows (see fig 3, pg 12). The 48V battery pack (IV) is charged by two solar panels (I) which are being regulated by the *Prostar* PWM charge controller (X). The battery output goes to the main contactor (V). The contactor is an electromechanical relay that is controlled by a toggle switch, ideally placed in the driver's compartment. When the switch is flipped on, the solenoid in the relay is energized and connects the high voltage contacts (48v) completing the circuit from the batteries to the motor controller (III). Once the motor controller is powered, the driver will control the speed of the motor with a 0-5kΩ potentiometer (pot) integrated in a foot pedal throttle . The motor controller receives the signal from the pot and as the resistance increases, the motor speed increases.

To reverse the motor we will use a reversing contactor (VII) which conceptually works very similar to the main contactor. Instead of it being switched on or off, the reversing contactor has two states: forward or reverse. Each state has it's own solenoid which are each powered by a Single Pole Double Throw (SPDT) switch. When the switch is flipped, the opposite solenoid is then energized, safely reversing the polarity of the motor and thus the direction it spins.

For protection we have placed a 250A ceramic fuse (XI) on the positive side of the battery bank. If for any reason the system current exceeds 250A, the fuse will blow and the power will be cut off from the contactor and the motor controller.

Another protective component we have implemented is the precharge resistor. Our motor controller has a bank of capacitors that is connected to it's inputs. An uncharged capacitor's resistance is so little, that when a voltage is applied to it, it will appear to short circuit. This means that when a contactor without a precharge resistor closes, there will be a large voltage difference and sudden high current (known as "inrush current") across the contactor. This can result in the damage or, in extreme cases, welding of the relay contacts. To prevent this, we connected a precharge resistor in parallel with the main contactor. This allows for low current charging of the capacitor bank prior to the closing of the contactor. When the capacitors are charged, their resistance increases therefore decreasing the inrush current and allowing for the safe closing of the main contactor.

The last component for protection is the coil suppression diode. When the solenoids in each of the contactors are shut off, they will try to resist the sudden drop in current by using their own stored magnetic field to produce a high voltage spike. To prevent voltage spike arcing, a diode is placed parallel with each solenoid. The diode then allows the solenoid to draw current from itself and dissipate voltage through losses (resistance) in the coil wires. (see Appendix E)

Finally, to measure data, we will be using a Grin Technologies *Cycle Analyst*. The Cycle Analyst works as a standard ammeter and shunt configuration. It measures the voltage drop across a shunt that is placed on the negative side of the battery bank.The Cycle Analyst then translates the voltage measured to the amount of current running through it. On top of measuring current, the Cycle Analyst will also measure net amp hours. This allows the driver to know how much energy they have drawn from the battery and how much of the 35Ah capacity remains.

Component Layout

The layout of the major electrical components is as follows. The motor controller, main contactor, reversing contactor, main fuse, cycle analyst shunt, and charge controller will be mounted on a lexan board that is then mounted on the car frame behind the driver's seat. The batteries themselves will be mounted underneath the driver's seat and reinforced by angle aluminum and diamond plate provided by the mechanical team.Our two solar panels will be mounted on supports and act as a roof for the car. These panels will be stacked on top of each other while the car is driving. When the car has stopped and is ready to charge, the top panel that is mounted on a sliding rack will slide out and allow us to utilize both panels for charging.

Wiring Diagram

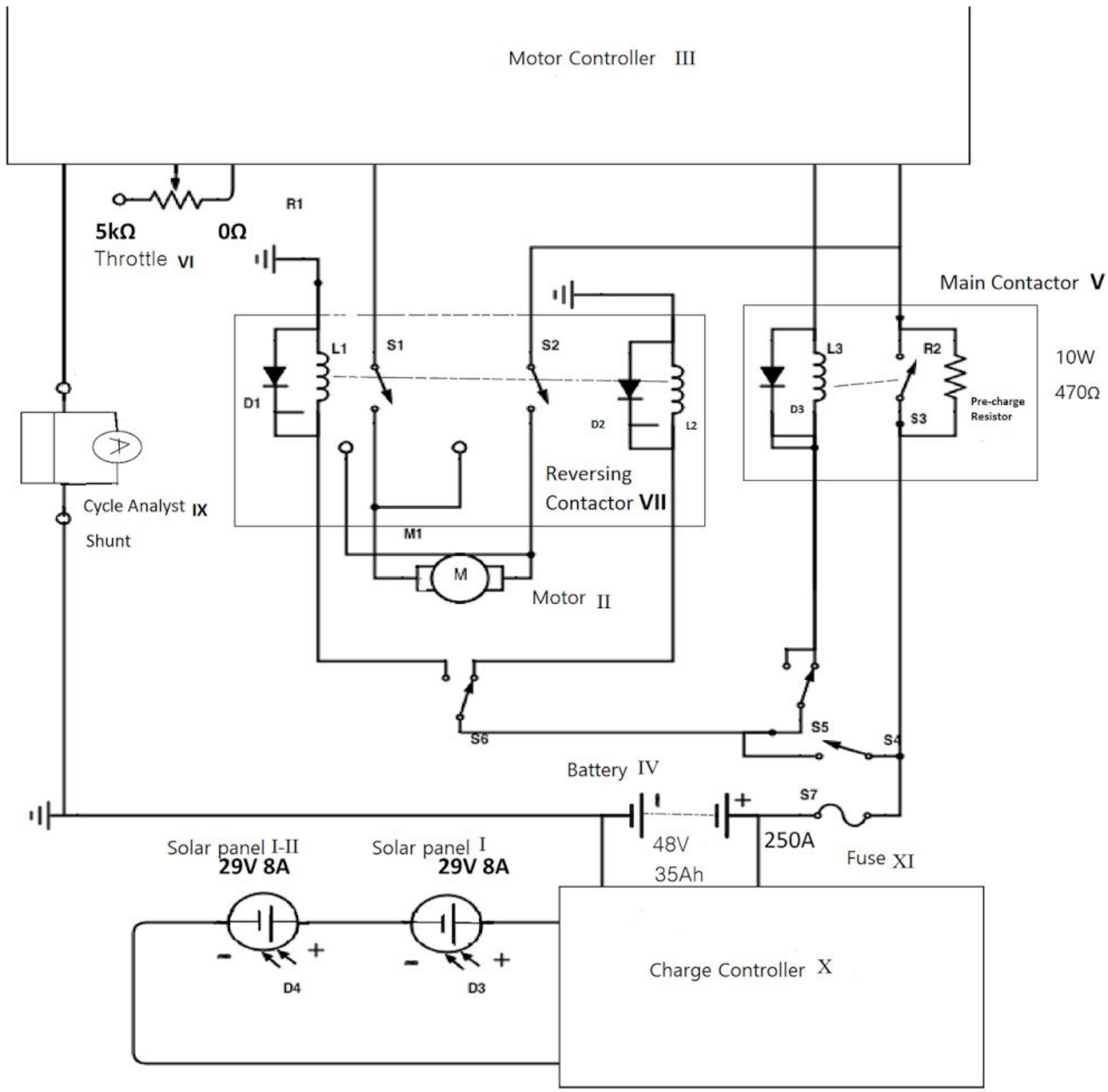


fig.3

Equipment List and Cost

1) Solar Panel

2) Motor

3) Motor Controller

4) Battery

5) Main Contactor

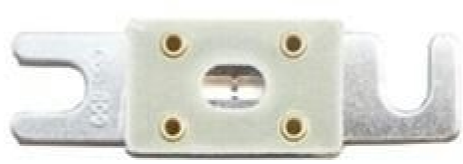
6) Throttle (foot pedal)

7) Reverse Contactor

8) Suppression Diode

9) Cycle Analyst

10) Charge Controller



11) Fuse

12) Precharge Resistor

fig. 4

Equipment List

Part	Brand	Model	Specifications	Total
Solar Panel	Yingli Solar	YL235P - 29b	- 29.5V - 7.97A(8A)	Free, provided from previous SURP projects
Motor	Motoenergy	ME0909	- 12-48V and 4 Hp cont. (12.8Hp peak) - 4000 RPM at 48V	$385.00
Motor Controller	Alltrax	AXE4834	- 24-48V - 300A	$325.00
Charge Controller	Morningstar	PS-15M 48V	- digital screen - 48V - 15A	$190.00
Motor Fuse	ANN	ANN250	- 5/16” terminal slots - 250A	$20.00
Precharge Resistor	Xicon	280-CR10-250-RC	- 470 ohms - 10 watt	(4) $10.00
Main Contactor	Albright	SW 180	- 36-48V - 200A cont.	$85.00
Reverse Contactor	Albright	SW 182	- 48V - 200A cont.	$104.95
Throttle	Curtis	FP - 6	- 0-5K ohms - 5 wiring- outlets	$125.00
Battery	Power Patrol SLA(sealed lead acid)	SLA1155	- 12V - 35Ah	(1) $74.20 (3) Donated by James Madison High School
Cycle Analyst	Grin Technologies	CA-HC-WSH UNT	- 10-650V - 300A (shunt)	$210.00
Battery Charger	Stanley	GBCPRO	- 12V 48V - 3 stage battery charger	$99.76

fig. 5

Test Approach

The testing will be conducted in two phases. The first being a off-frame functionality bench test to confirm that our components are working properly. The second phase will be an on-frame test in which we will collect our necessary data. Our primary source of data collection will be from the cycle analyst. The cycle analyst acts as a voltmeter and ammeter. We will be testing the length of battery discharge at 3 different speeds; high, medium and low. We expect that the batteries will discharge much faster during the on-frame test as the added load weight of the vehicle including occupants on the motor and will require much more power to achieve comparable motor speed or Revolutions Per Minute (RPMs).

Performance

Limitations

There are two major limitations to the electrical performance of the SolGo ARV. The first is speed. The projected top speed is 12-15 mph and that is due to the weight of the vehicle and the horsepower of the motor. The second limitation is range. This is due to the capacity of our batteries and the fact that the solar panels will not be charging when the car is driving.

Constraints

There are also three major constraints that our team faces with this project. The first is budget. We are limited to $2000 dollars in equipment expenditures. Because of this, we cannot purchase more sophisticated technologies for batteries, motor, motor controller, etc. The second constraint is time. The project timeline is 10 weeks long. A more sophisticated car would require a much longer time period to properly design, build, and test. The third and final constraint is weather. In order to properly test the car the weather must be sunny and dry.

Project Timeline (also, see fig 6, pg 17)

Week One (6/8-6/15):
- Initial Project Meetings (6/8)
- Part List Assembled and Finalized (6/8-6/14)

Week Two(6/15-6/22):
- Concept Familiarization (6/15-6/22)
- Preliminary/Abstract Design (6/15-6/22)

Week Three (6/22-6/29):
- Library Workshop (6/24)
- Finalize Design (6/22-6/29)

Week Four (6/29-7/6)
- Off-frame Assembly (6/29-7/2)

Week Five (7/6-7/13):
- Digital Storytelling Workshop (7/7)
- Analyze Test Phase 1 Data (7/9-7/11)
- Complete Project Design Document (7/13)

Week Six (7/13-7/20):
- Parts Ordered (7/13)

Week Seven (7/20-7/27)
- Parts Received (7/21)

Week Eight (7/27-8/3)
- Begin On-frame Assembly (7/27)

Week Nine(8/3-8/10)
- Test Phase (8/3)
- Analyze Test Phase Data (8/4)
- Finish Final Report (8/5~)

Week Ten (8/10-8/17)
- Customer Delivery and Acceptance (8/10)
- Finish Final Report (~8/17)
- Finish PowerPoint (~8/17)

August
Digital Storytelling Video (8/17-8/21)
September
Presentation during STEM Week (9/8)

Project Gantt Chart

Name	Begin date	End date
Initial Project Meeting	6/8/15	6/8/15
Parts List Assembled and Fin...	6/8/15	6/14/15
Concept Familiarization	6/15/15	6/22/15
Preliminary/Abstract Design	6/15/15	6/22/15
Finalize Designs	6/22/15	6/29/15
Project Design Report	6/22/15	7/10/15
Library Workshop	6/24/15	6/24/15
Digital Storytelling Workshop	7/7/15	7/7/15
Parts Ordered	7/13/15	7/13/15
Writing Workshop	7/15/15	7/15/15
Parts Received	7/21/15	7/21/15
Begin On-frame Assembly	7/27/15	7/30/15
Test Phase	8/3/15	8/3/15
Analyze Test Phase Data	8/4/15	8/4/15
Finish Final Report	8/5/15	8/17/15
Finish Powerpoint	8/5/15	8/17/15
Customer Delivery and Acce...	8/10/15	8/10/15
Digital Storytelling Video	8/17/15	8/21/15
Present During STEM Week	9/8/15	9/8/15

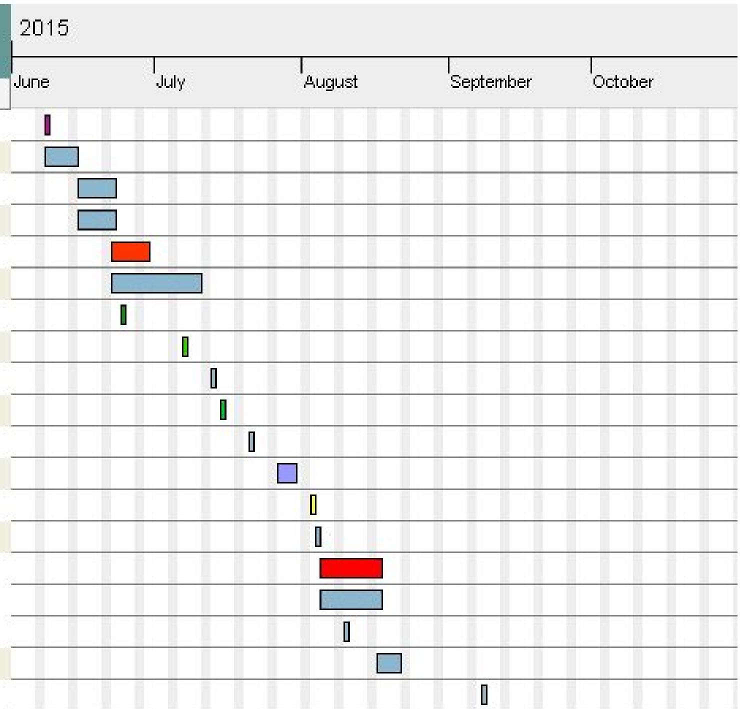


fig. 6

Summer Undergraduate Research Participants

Klaus Bartels - Faculty Adviser

Nicholas Jones - Industry Partner and Consultant

Dominic Ochoa - Team Leader

Kevin Castano - Team member

Yeojin Park - Team Member

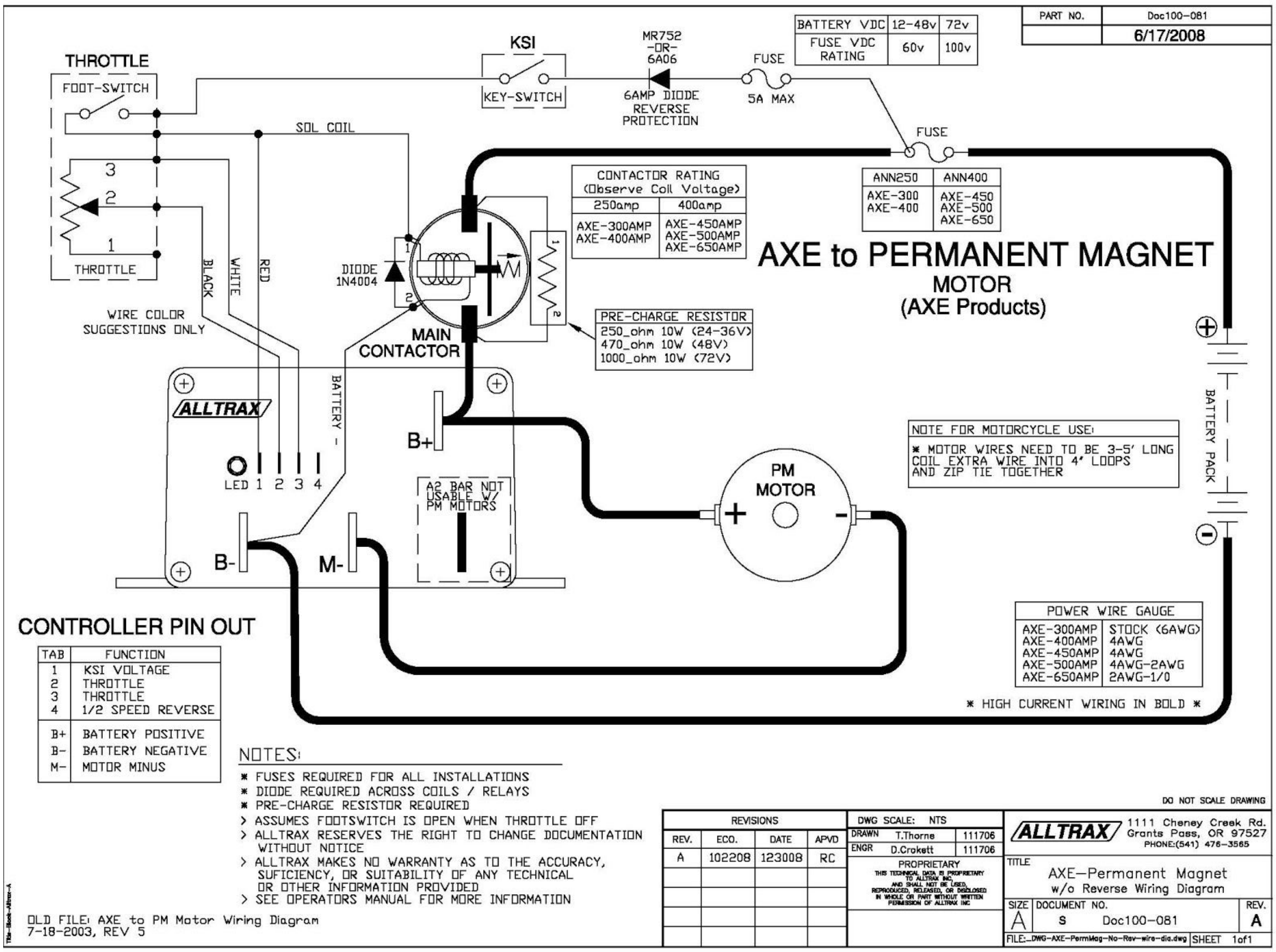
Julio Banda - Team Member

References

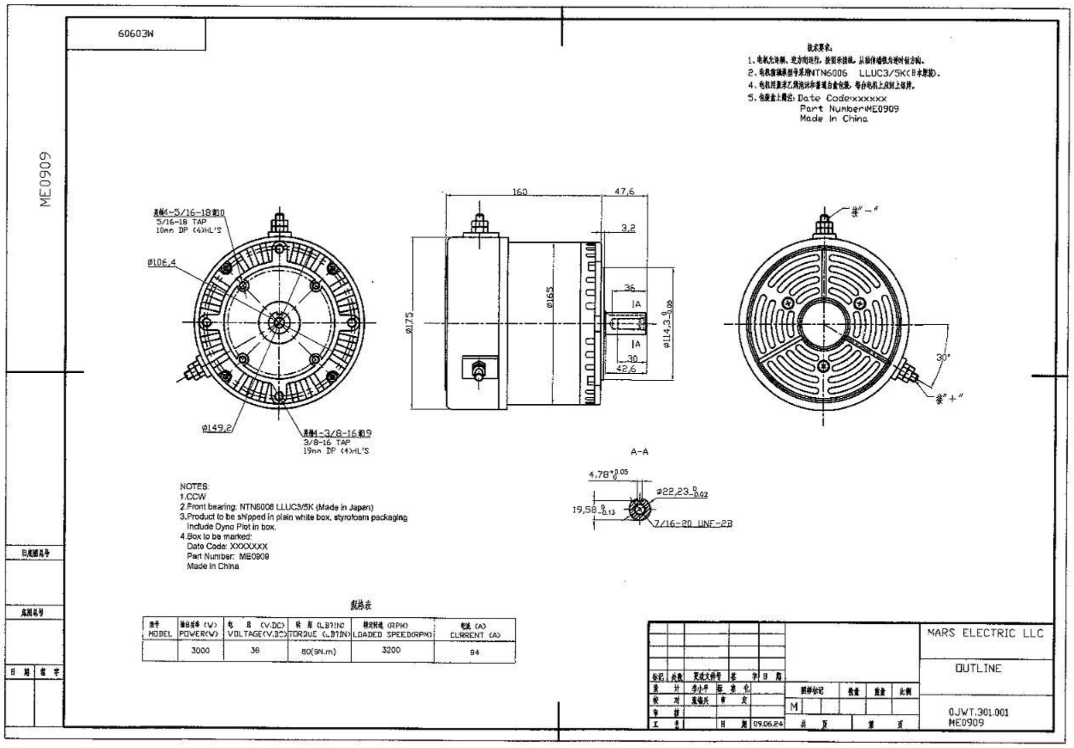
- http://www.instructables.com/id/Lifepo4-solar-storage-battery-bank/?ALLSTEPS
- http://www.solar-electric.com/deep-cycle-battery-faq.html
- http://www.mpoweruk.com/lithium_failures.htm
- http://batteryuniversity.com/learn/article/absorbent_glass_mat_agm
- http://www.scribd.com/doc/234785801/Lithium-Polymer-Battery#scribd
- http://www.solar-electric.com/mppt-solar-charge-controllers.html
- http://www.diyelectriccar.com/forums/showthread.php/precharge-why-do-need-do-do-25419.html
- *Electrical Subsystem for Solar Panel Electric Cart.* Luna, Favela, Trujillo. Rojas. 5 September 2013

Appendix

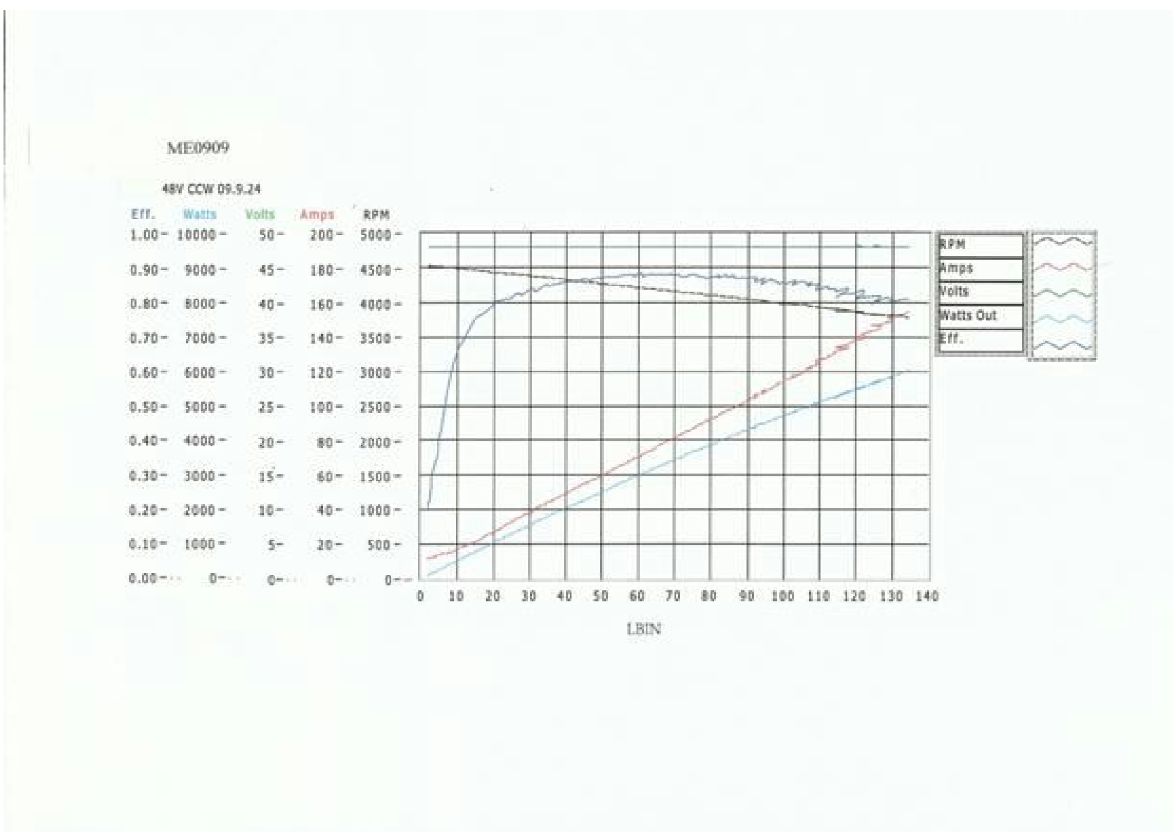
Appendix A: Motor Controller Permanent Magnet Wiring Diagram



Appendix B: Electric Motor Measurement Diagram



Appendix C: Motor Power Curve



Appendix D: Charge Controller Specifications

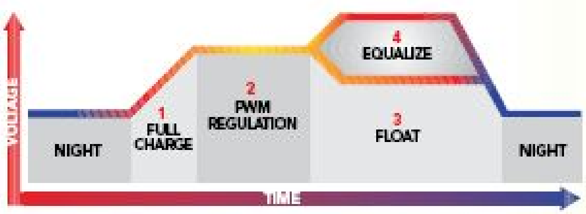
PROSTAR™ TECHNICAL SPECIFICATIONS

ProStar Options:

- Digital meter
  - – Highly accurate voltage and current display
  - – Low self-consumption (1 mA)
  - – Includes manual disconnect button
  - – Displays 5 different protection functions and disconnect conditions
  - – Self-diagnostics (self-test) provides a comprehensive test of the ProStar —
    - Displays 9 different controller status parameters, including temperature
    - Displays detected faults
- Positive ground
- Remote temperature probe

Optimized Battery Charging:

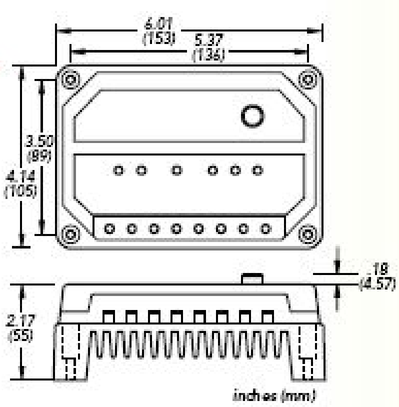
The ProStar has 4 stages of charging to provide increased battery capacity and life.



Mechanical Specifications:

Weight:
12 oz
(0.34 kg)

Wire Size:
#6 AWG
(16 mm²)



ProStar Versions:

	PS-15	PS-30	PS15M-48V
Rated Solar Current	15A	30A	15A
Rated Load Current	15A	30A	15A
System Voltage	12/24V	12/24V	48V
Options:			
Digital Meter	yes	yes	standard
Positive Ground	no	yes	yes
Remote Temp. Probe	yes	yes	yes

Battery Voltage Setpoints*

	Gel	Sealed	Flooded
Regulation Voltage	14.0	14.15	14.4
Float	13.7	13.7	13.7
Equalization	n/a	14.35	14.9/15.1
Load Disconnect	11.4	11.4	11.4
Load Reconnect	12.6	12.6	12.6

Note: values are for 12V. Use 2X for 24V and 4X for 48V.

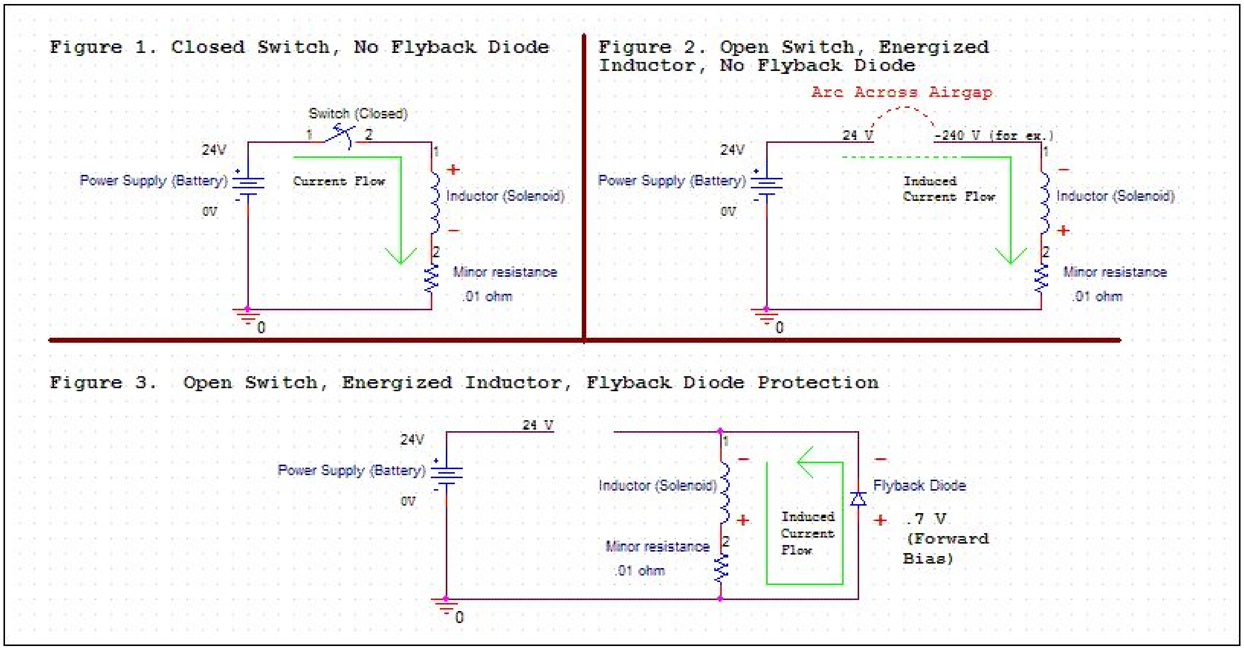
Electrical Specifications:

	12V	24V	48V
Temp. Comp. (mV/°C)*	– 30mV	– 60mV	– 120mV
Accuracy	40mV	60mV	80mV
Min. voltage to operate	8V	8V	15V
Self-consumption	22mA	25mA	28mA
LVD current coefficient**	– 20mV	– 40mV	– 80mV
Charge algorithm	PWM, constant voltage		
Operating temperature	– 40°C to + 60°C		
Digital Display:			
Operating temperature	– 30°C to + 85°C		
Voltage accuracy	0.5%		
Current accuracy	2.0%		
Self-consumption	1 mA		

* 25°C reference
** per amp of load

WARRANTY: ***Five year warranty period. Contact Morningstar or your authorized distributor for complete terms.***

Appendix E: Coil Suppression Diode Working Theory



Appendix F: Solar Panel Specifications

YL 235 P-29b / 1650x990 SERIES

ELECTRICAL PARAMETERS

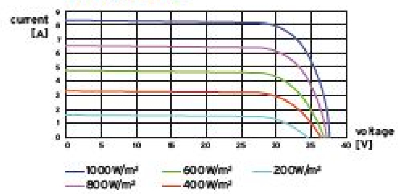
Electrical parameters at STC (1,000 W/m², 25°C, AM1.5 according to EN 60904-3)

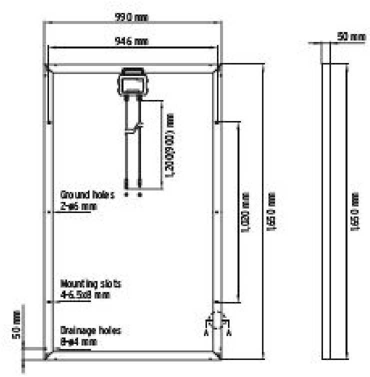
Module type		YL 210 P-29b	YL 215 P-29b	YL 220 P-29b	YL 225 P-29b	YL 230 P-29b	YL 235 P-29b
Power output	[W]	210.0	215.0	220.0	225.0	230.0	235.0
Power output tolerances	[%]	+/- 3	+/- 3	+/- 3	+/- 3	+/- 3	+/- 3
Module Efficiency	[%]	12.9	13.2	13.5	13.8	14.1	14.4
Voltage at Pmax, V_{mpp}	[V]	28.5	29.0	29.0	29.5	29.5	29.5
Current at Pmax, I_{mpp}	[A]	7.37	7.41	7.59	7.63	7.80	7.97
Open circuit voltage V_{oc}	[V]	36.0	36.0	36.5	36.5	37.0	37.0
Short circuit current I_{sc}	[A]	7.95	8.10	8.15	8.28	8.40	8.54
Max. system Voltage	[V]	1,000 VDC					

Parameters of the thermal characteristics

NOCT (Nominal Operating Cell Temperature)	[°C]	46 +/- 2
Temperature coefficient beta of I_{sc}	[1/K]	+ 0.0006
Temperature coefficient alpha of V_{oc}	[1/K]	- 0.0037
Temperature coefficient gamma of P_{mpp}	[1/K]	- 0.0045

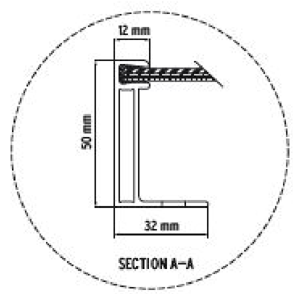
IV CURVES





MECHANICAL PARAMETERS

Dimensions (length [mm] / width [mm] / thickness [mm])	1,650 / 990 / 50
Thickness with junction box [mm]	50
Weight [kg]	19.8
Junction box (manufacturer / protection degree / number of diodes)	CIXI / IP65 / 6
Junction box dimensions (length / width / thickness [mm])	151 / 122 / 25
Positive cable & negative cable (manufacturer / length [mm] / cable cross-section [mm²])	CIXI / 1,200 (900) / 4.0
Plug connector (manufacturer / type / protection degree)	MC4 / UV resistance and self-locking / IP67
Front cover (material / thickness [mm])	Tempered Glass, 3.6mm
Cell type (quantity / technology)	60 / polycrystalline / 156 x 156
Encapsulation materials	Ethylene Vinyl Acetate (EVA)
Rear cover (material / thickness [mm])	Le - PET - PVDF / 0.287
Frame (material)	robust anodized aluminum alloy



Electrical equipment, check with your installer

OPERATING CONDITIONS

Operating temperature [°C]	- 40 to + 85
Max. wind load / Max. snow load [Pa]	2.4K / 5.4K

PACKAGING

Number of modules per box	20
Box size (length [mm] / width [mm] / depth [mm])	1700 / 1,140 / 1,165
Box Gross weight in kg	450
Boxes per pallet	1

* The data does not refer to a single module and they are not part of the offer, they serve for comparison only to different module types.

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Subject to modifications and errors

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