Low Carbon Footprint Hybrid Battery Charger

Project Proposal

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1. Introduction

The aim of the Low Carbon Footprint Hybrid Battery Charger (LCC) project is to charge a battery for vehicular applications using the renewable energy resources of photovoltaic arrays and a wind turbine. The project will emphasize efficient energy collection and usage by developing algorithms to maximize renewable energy use and minimize utility A.C. energy use. In addition, the user will have the ability to choose three different modes based on how they want to charge the battery. The modes of operation are: maximum battery life, minimum charge time, and emergency charge. The completed system will require:

1. using photovoltaic arrays and a wind turbine as renewable energy sources
2. a power control system to optimize use of renewable energy
3. a microcontroller based user interface
4. charging systems for the stationary and mobile battery

2. High Level Block Diagram

Figure 2.1 depicts the high level system block diagram. This flow chart shows primary objectives in white and extended objectives shaded. If time permits the shaded blocks will be implemented, but are not necessary for basic functionality. In Figure 2.1, the dotted lines represent control signals and the solid lines represent power flow. The control signals will be used to control the flow of power and transmit data for the user interface. Power flow is the path the power will follow through the charging process to reach the mobile battery.

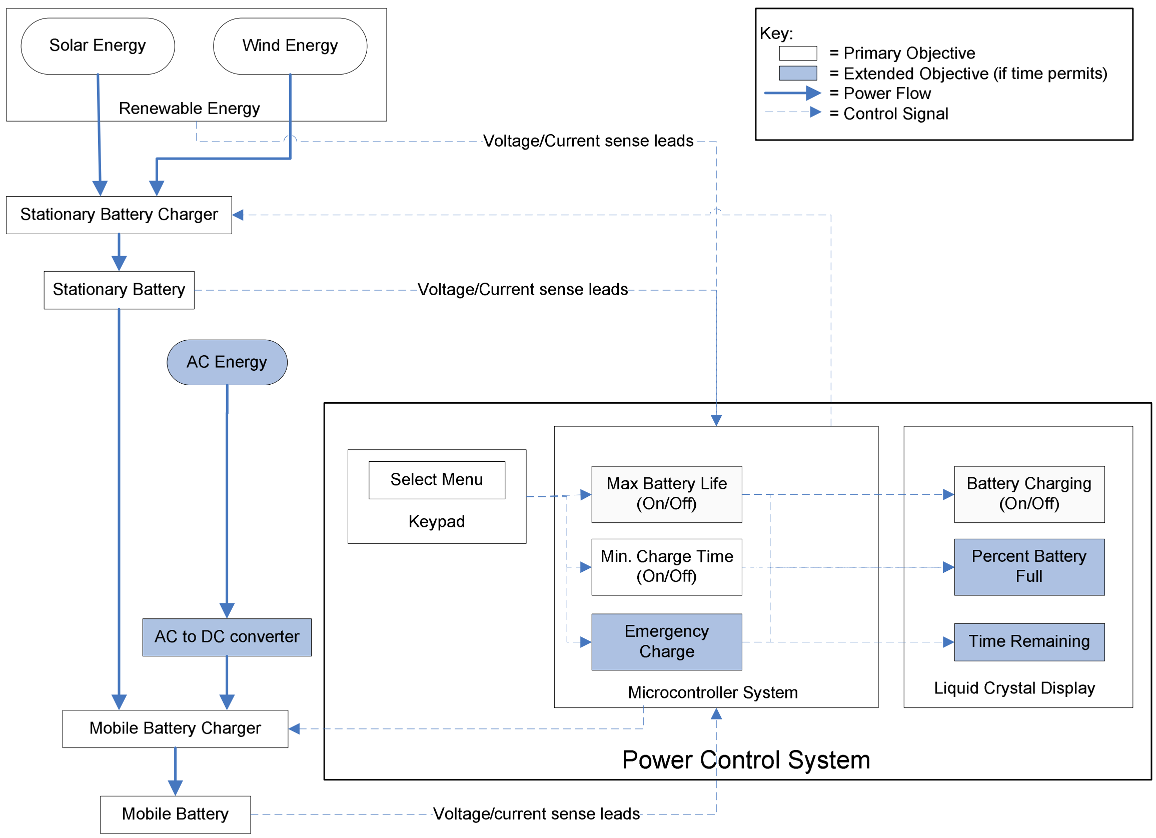


Figure 2.1: High Level System Block Diagram

2.1 Subsystems

Refer to Figure 2.1 as each subsystem is briefly explained.

2.1.1 Renewable Energy

The renewable energy subsystem includes wind and solar energy. Ideally, wind energy would be provided by a full scale wind turbine, and solar energy would be provided by a photovoltaic array. For proof of concept, a DC motor will drive a DC generator simulating a scaled down version of a wind turbine. Photovoltaic cells will be used to collect power from the sun.

2.1.2 Stationary Battery Charger

The stationary battery charger will process the two renewable energy sources to generate a single regulated output voltage capable of charging a stationary battery. The battery charger will always operate in a mode consistent with maximizing the stationary battery's life, and will always be charging as long as the renewable power does not drop below a certain threshold. The minimum power threshold has not yet been determined.

2.1.3 Stationary Battery

The stationary battery will store renewable energy until power is needed to charge a mobile battery. The stationary battery will be composed of Ni-MH to accommodate deep cycle discharging, trickle charging, a relatively high number of charge cycles, and constant battery capacity throughout its lifetime [1]. When the battery can only hold a 80% charge, it will be assumed the battery has reached the end of its life [2].

2.1.4 Mobile Battery Charger

The mobile battery charger subsystem is similar to the stationary battery charger subsystem. However, the mobile battery charger will have the ability to switch modes. The mobile battery charger will accept power from the stationary battery and the (paralleled) stationary battery charger. If the extended objectives are met, this charger will also have the ability to use AC power if no other power is available.

2.1.5 Mobile Battery

The mobile battery will be an electric car battery. For proof of concept, this project will use a Panasonic LC-RA1212P 12V lead-acid battery. The rated capacity for this battery is 12Ah [3]. The Panasonic datasheet for this battery is included in Appendix A. Maximum battery life and minimal charge time characteristics for this battery will need to be researched.

2.1.6 Voltage/Current Probes

Voltage and current sensors will be used to detect available power from the renewable sources. The sensor outputs will be used within the microcontroller system to determine what power sources are used to charge the mobile battery. In addition, the sensors will be used to control the charging algorithm for each battery. If the extended objectives are completed, AC power can be used to charge the mobile battery if the charge state of the stationary battery is inadequate.

2.1.7 Power Control System

The power control system will be an 8-bit microcontroller based module responsible for routing the power flow in a manner that maximizes renewable energy utilization. It will analyze data from the user and from the voltage and current sensors to achieve optimum battery charging efficiency.

2.1.8 Mobile Charger User Interface Input

A keypad will be used as the power control system user interface. From the keypad the user will be able to choose the desired mode of operation based on his or her current circumstances. The three modes of operation are:

- Maximum Battery Life
    - Only the stationary battery is used to charge the mobile battery. Renewable energy sources will continue to provide energy to the stationary battery and to the mobile battery during charging. This method will charge the mobile battery in such a way as to maximize battery life. As an extended objective, AC power may be used in combination with the stationary battery in this step to charge the mobile battery.
- Minimum Charge Time
    - Minimal charge time mode will contain the same sources as maximum battery life mode. However, a different charging algorithm will be used in minimal charge time mode to charge the mobile battery as fast as possible.
- Emergency Charge:
    - As an extended objective, an emergency charge mode may be implemented. This mode will use AC power to charge the battery in emergency circumstances. By using AC power, the user can charge the battery anywhere a standard 120V power outlet is available.

2.1.9 Mobile Charger User Interface Output

A LCD controlled by the power control system will be used for interface output. The power control system will have the ability to collect and analyze data to provide the user with the following information:

- battery charging status (charging on/off)
- extended objectives
    - the charge percentage of maximum capacity
    - the time remaining until the battery is charged to maximum capacity
    - a battery longevity indicator that will indicate approximately how many charge cycles the battery will tolerate before replacement is needed

3. Software Flowcharts

The software will include two separate microcontroller systems, one for the stationary battery charger and one for the mobile battery charger. The mobile battery charger software will handle user inputs and outputs. The High Level Mobile Battery Charger Software Flow Chart is shown in Figure 5.1, where extended objectives are shaded.

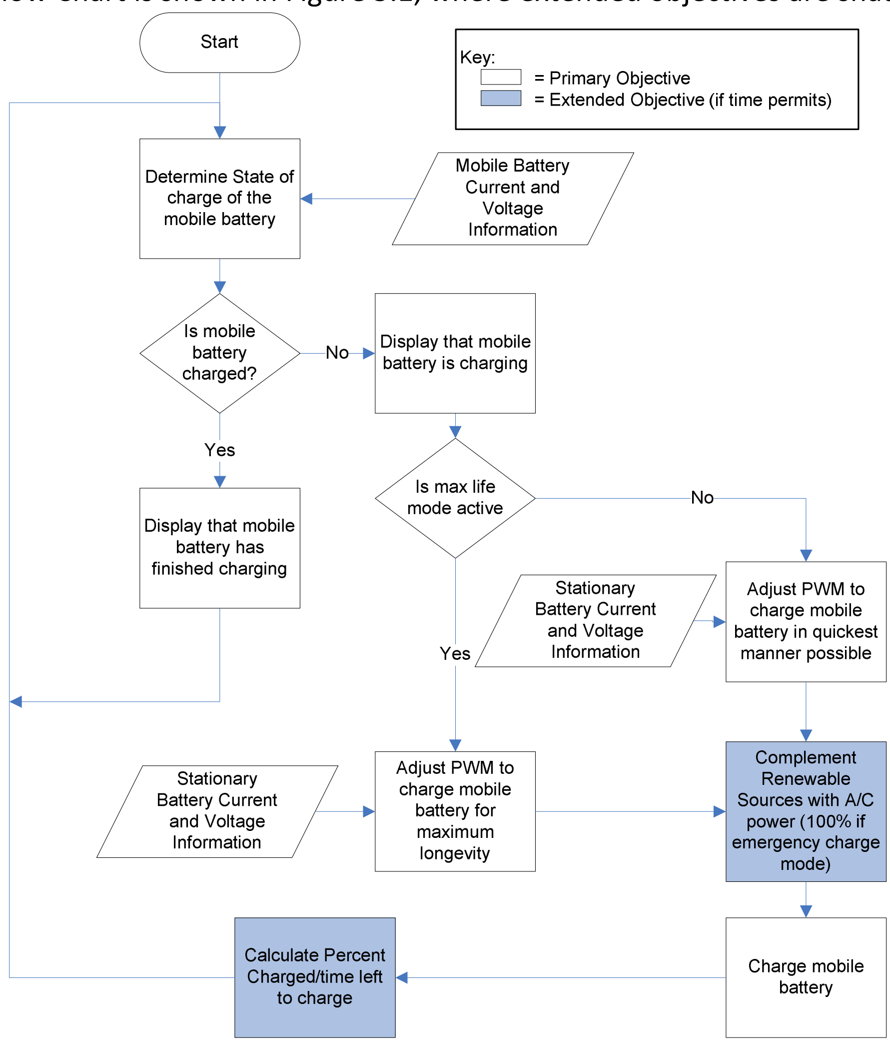


Figure 5.1: High Level Mobile Battery Charger Software Flow Chart

Depending on which mode is active, the microcontroller determines the correct pulse width modulated signal to either maximize battery life or minimize charge time. Also, in the extended functionality, an AC source will be used in either an emergency mode or to complement the renewable energy to charge the battery in either charge mode. Initially, the only output will be the status of the charge i.e. charging or not charging. As part of the extended objectives, the user output will additionally display time remaining to charge, percent of the battery charged, and a battery longevity indicator. The battery longevity indicator would approximate how many charge cycles the battery will tolerate before replacement is needed. The High Level Stationary Battery Charger Software Flow Chart is shown in Figure 5.2. The stationary battery charger will function in a manner similar to the mobile battery charger except it will always be in the maximum battery life mode.

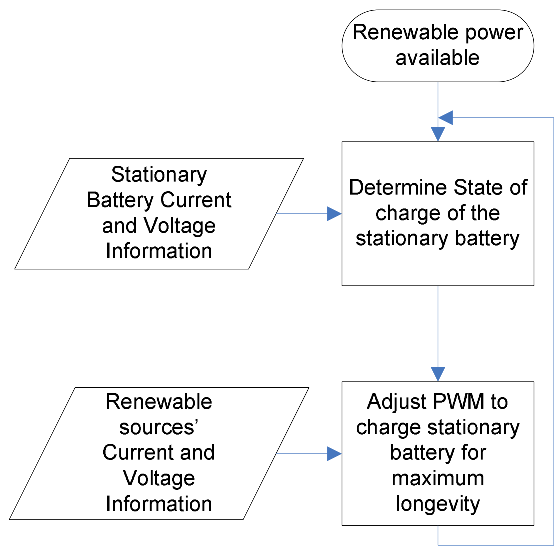


Figure 5.2: High Level Stationary Battery Charger Software Flow Chart

4. Specifications

Functional requirements and performance specifications for all subsystems and software are given below.

4.1 Renewable Energy

The photovoltaic arrays shall provide sufficient energy to charge the mobile battery given 1.470 sun hours per day in Peoria, Illinois with 0 M.P.H. winds [4]. Conversely, the wind turbine shall provide sufficient energy to charge the mobile battery given a an average wind speed of 12 M.P.H at a height of 50m and 0.000 sun hours per day [5].

4.2 Stationary Battery Charger

The stationary battery charger shall require circuitry capable of handling the combined maximum current and maximum voltage of the photovoltaic arrays and the wind turbine. The maximum input specifications for current and voltage shall be 24V and 42A.

4.3 Stationary Battery

The stationary battery shall have a capacity of at least 180Wh [3]. The stationary battery shall be charged with less than 125% charge input to maximize the battery life [3]. Maximum battery life of the stationary battery shall be equal to at least 300 charge cycles.

4.4 Mobile Battery Charger

The mobile battery charger shall be capable of charging the mobile battery within 12 hours [2]. The charger circuitry shall be capable of receiving and outputting at least 5.0A of current, and a voltage of 15V [3].

4.5 Mobile Battery

The mobile battery charger requires a maximum current of 4.8A, and a voltage of 14.5V-14.9V to recharge the battery [3].

4.6 Power Control System

The power control system shall update its charging algorithm as the battery charge state dictates. The power control system shall be operational between 0C and 45C to protect all batteries in the system [1].

4.7 Software

The software for the power control system shall process the user's preferred charge mode. There shall be three charge modes: Maximum Battery Life, Minimum Charge Time, and Emergency Charge. The user outputs shall be: Battery Charging, Percent Battery Full, and Time Remaining.

5. Standards and Patents

The standards shown in Table 8.1 directly relate to electric vehicle charging systems, photovoltaic stand-alone systems, and safety.

Relevant Standard	Description
IEC 62124	Photovoltaic (PV) stand-alone systems Design verification [6]
IEC 61173	Overvoltage Protection for Photovoltaic (PV) Power Generating Systems [6]
IEEE 1013	Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems [6]
IEEE 485-1997	IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications [7]
UL 2202	Electric Vehicle Charging System Equipment [8]
UL 2231-1	Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: General Requirements [8]
UL 2231-2	Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems [8]
UL 2231-2	Plugs, Receptacles and Couplers for Electric Vehicles [8]

Table 8.1: Relevant Standards

The patents shown in Table 8.2 relate to systems similar to a hybrid battery charger for an electric vehicle.

Relevant Patents	Description
U.S. Patent #5646507	Battery charger system [9]
U.S. Patent #6768285	Power system for converting variable source power to constant load power [9]
U.S. Patent #4024448	Electric vehicle battery charger [9]
U.S. Patent #5144218	Device for determining the charge condition of a battery [9]
U.S. Patent #6204645	Battery charging controller [9]
U.S. Patent #6677730	Device and method for pulse charging a battery…[9]

Table 8.2: Relevant Patents

6. Analytical Evaluations

The estimated power usage per day is shown in Figure 9.1. This calculation was used to determine the number of photovoltaic modules needed to meet the specified power and time requirements with 0 M.P.H winds. To estimate the number of sun hours in Peoria, IL, the analytical values from Advanced Energy Group (AEG) were used. Table 9.1 shows the values acquired from AEG for Chicago and St. Louis. Figure 9.3 suggests that averaging the values of Chicago and St. Louis creates an accurate estimation for the number of sun hours in Peoria, IL. However, for the worst case calculation, the low sun hour value for Chicago was used. Using the DC load value and the amount of Joules generated from one P.V. module, the number of P.V. modules need for a worst case scenario is shown in Figure 9.3.

Joules/day load = Mobile Battery Wh * 3600 sec * Charging Inefficiency
648,000 Joules/day load = 12 Ah *12 V *3600 sec *1.25

Figure 9.1: DC Load Calculation [4]

Joules/day/module = 1e3 * P.V. module area * P.V. module efficiency * 3600 sec * Sun Hours
285768 Joules/day/module = 1e3 * 0.652m * 0.639m * 0.16 *3600 sec * 1.47 kWh/m^2/day

(Joules/day load)/(Joules/day/module) = 2.26 Modules needed to meet charging requirement

Figure 9.3: Module Quantity Calculation [4]

Figure 9.2: Midwest Average Low Peak Solar Insolation [5]

Peoria Averaged Analytical Sun Hour Data				
		High	Low	Average
IL	Chicago	4.08	1.47	3.14
MO	St. Louis	4.87	3.24	4.38
IL	**PEORIA**	**4.475**	**2.355**	**3.76**

Table 9.1: Averaged Sun Hour Data For Peoria, IL [4]

A small scale wind turbine was desirable for a cost affective product. As a result, a smaller, cheaper wind turbine was chosen. Its specifications were then compared against the worst case power generation for Peoria, IL. Based on the U.S. Department of Energy's statistics, the average wind speed at a height of 50 meters in Peoria is 14.3-15.7 M.P.H [10]. Based on Figure 9.1, 4.0 kWh/week are required to provide enough energy to fully charge the mobile battery everyday of the week. This translates to 0.572 kWh/day required daily. The wind turbine specifications shown in Appendix A, Figure A-2 define that with wind speeds of 12 M.P.H., 1.2kWh/day of energy will be produced. Both the wind speed and power specifications will be met with this cost effective wind turbine.

7. Schedule

The Gantt Chart shown in Figure 10.1 summarizes the timeline and distribution of responsibilities of each member until the completion of the project.

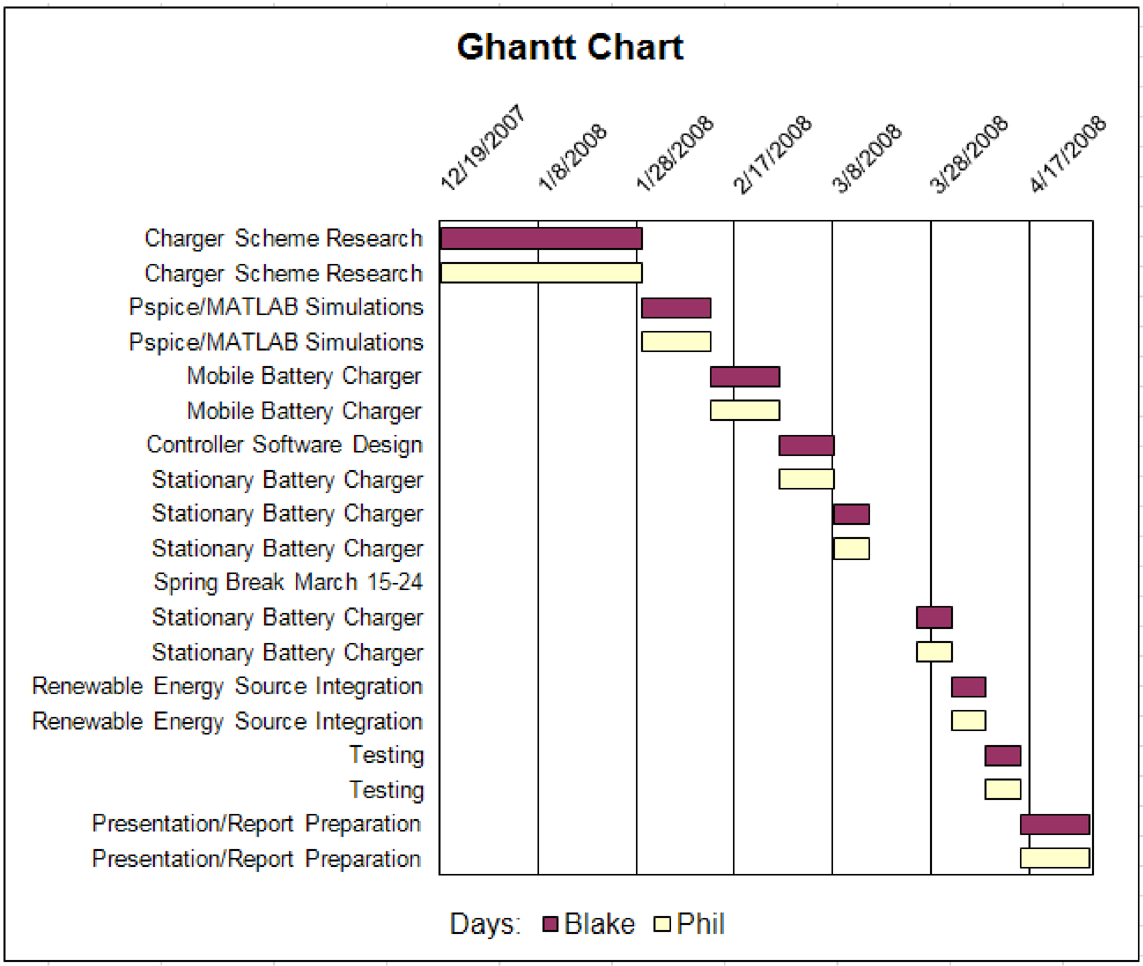


Figure 10.1: Gantt Chart

8. Equipment

Table 11.1 shows all equipment that should be purchased before the end of the fall 2007 semester.

Equipment	Quantity	Estimated Unit Cost	Estimated Total Cost
Kyocera KC50T Photovoltaic Module	3	$299.00	$897.00
Southwest Wind Company 400W Air-X Wind Turbine	1	$555.00	$555.00
Mast for Wind Turbine	1	$130.00	$130.00
Optima D35 Lead-Acid Battery	1	$178.95	$178.95
Micropac535 Development Board	1	$0.00	$0.00
Total:			$1,760.95

Figure 11.1: Equipment Needed

5. Appendix A

Figure A-1

VALVE-REGULATED LEAD ACID BATTERIES: INDIVIDUAL DATA SHEET

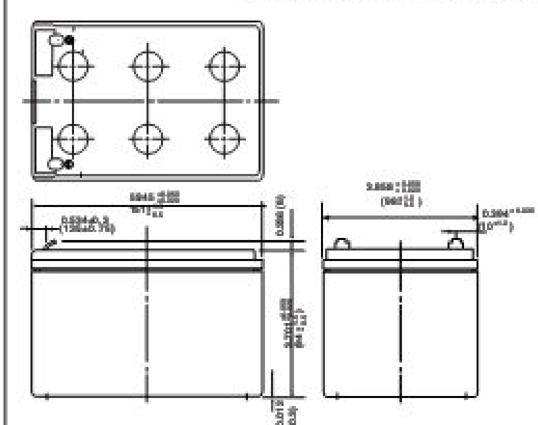
LC-RA1212P

For main and standby power supplies.
Expected trickle life: 3-5 years at 25°C, Approx. 5 years at 20°C.

Photo/Label for reference only.

Dimensions (mm)

Terminal type: Faston 187 or Faston 250



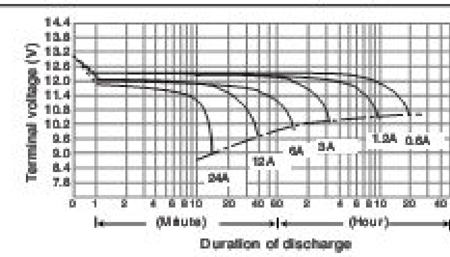
Battery case resin: Standard (UL94HB) Color is black.

Specifications

Nominal voltage		12V
Rated capacity (20 hour rate)		12Ah
Dimensions	Length	5.945 inches (151.0 mm)
	Width	3.860 inches (98.0 mm)
	Height	3.702 inches (94.0 mm)
	Total Height*	3.937 inches (100.0 mm)
Approx. mass		8.36 lbs (3.8 kg)
Standard Terminals and Resin	UL94HB Faston 187	LC-RA1212P
	UL94HB Faston 250	LC-RA1212P1

* The total height with #250 terminal is 101.5mm.

Discharge characteristics 77°F (25°C) (Note)



Characteristics

Capacity (Note) 77°F (25°C)		20 hour rate (600mA)	12Ah
		10 hour rate (1130mA)	11.3Ah
		5 hour rate (2080mA)	10.4Ah
		1 hour rate (8100mA)	8.1Ah
		1.5 hour rate discharge Cut-off voltage 10.5 V	5.8A
Internal resistance		Fully charged battery 77°F (25°C)	Approx. 30mΩ
Temperature dependency of capacity (20 hour rate)		104°F (40°C)	102%
		77°F (25°C)	100%
		32°F (0°C)	85%
		5°F (-15°C)	65%
Self discharge 77°F (25°C)		Residual capacity after standing 3 months	91%
		Residual capacity after standing 6 months	82%
		Residual capacity after standing 12 months	64%
Charge Method (Constant Voltage)	Cycle use (Repeating use)	Initial current	4.8 A or smaller
		Control voltage	14.5V to 14.9 V (per 12V cell 25°C)
	Trickle use	Initial current	1.8 A or smaller
		Control voltage	13.6V to 13.8V (per 12V cell 25°C)

(Note) The above characteristics data are average values obtained within three charge/discharge. Cycles not the minimum values.

Duration of discharge vs. Discharge current (Note)

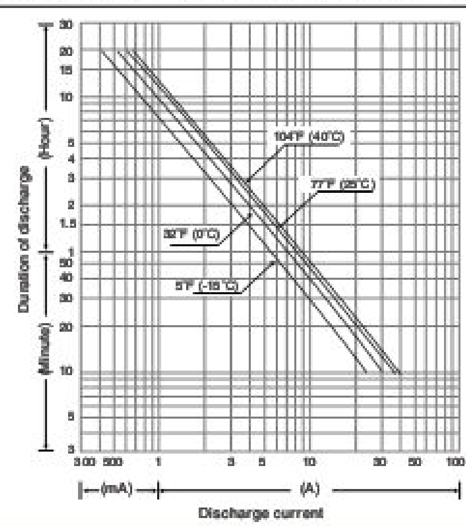


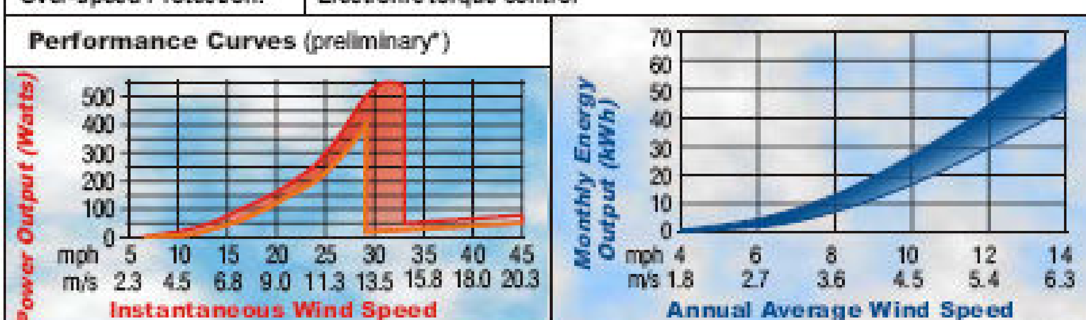
Figure A-2

AIR X SPECIFICATIONS

Patent Pending

Rotor Diameter:	46 inches (1.15m)
Weight:	13 lbs (5.85kg) (Shipping: 27"x15"x9" (686x38x228mm) / 17 lbs (7.7kg))
Mount:	1.5" schedule 40 pipe (1.9" OD, 48 mm)
Start-up wind speed:	7 mph (3.13 m/s)
Voltage:	12 and 24 VDC (36 and 48 VDC available soon)
Rated Power:	400 watts at 28mph (12.5m/s)
Turbine Controller:	Microprocessor-based smart internal regulator with Peak Power Tracking
Blades (three):	Carbon Fiber Composite
Body:	Cast aluminum (Air-X Marine is powder coated for corrosion protection)
Kilowatt hours per month:	38 kWh/mo @12mph (5.4m/s)
Warranty:	3 Year Limited Warranty
Survival Wind speed:	110 mph (49.2 m/s)
Over-speed Protection:	Electronic torque control

Performance Curves (preliminary*)



— Top Line - Non-Turbulent Site
— Bottom Line - Turbulent Site

*derived from field and wind tunnel testing

Southwest Windpower

(928) 779-9463
www.windenergy.com

6. References

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[10] "Wind Powering America: Illinois Wind Maps." U.S. DOE Energy Efficiency and Renewable Energy (EERE) Home Page. 4 Dec. 2007 <http://www.eere.energy.gov/windandhydro/windpoweringamerica/where_is_wind_illinois.asp>.