LOW CARBON FOOTPRINT HYBRID BATTERY CHARGER

PROJECT PROPOSAL

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PRESENTATION OUTLINE

- Project Summary
- Previous Research
  - Patents and Standards
- Project Description
  - System High Level Block Diagram
  - Subsystem Description and Specifications
  - Software High Level Block Diagram
- Datasheet
- Analytical Evaluations
- Project Equipment
- Project Schedule
PROJECT SUMMARY

- Charge a mobile battery for vehicular applications using renewable energy
  - Photovoltaic arrays
  - Wind turbine

- Develop microcontroller algorithms
  - Three Modes of Operation

- Emphasize efficient energy collection
  - Minimize utility A.C. energy
    - Store renewable energy in power bank until needed
PREVIOUS RESEARCH

What has been created by others?
- Solar powered vehicles
- Utility A.C. electric vehicles
- Wind turbine power generation
- Photovoltaic power generation
- Wind/Solar hybrid power generation
- Renewable energy charging a storage bank
- PWM battery charger
<table>
<thead>
<tr>
<th>Relevant Patents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Patent #5646507</td>
<td>Battery charger system for electric vehicles with quick charge and safe charge</td>
</tr>
<tr>
<td>U.S. Patent #6768285</td>
<td>Power system for converting variable source power to constant load power</td>
</tr>
<tr>
<td>U.S. Patent #4024448</td>
<td>Electric vehicle battery charger</td>
</tr>
<tr>
<td>U.S. Patent #5144218</td>
<td>Device for determining the charge condition of a battery</td>
</tr>
<tr>
<td>U.S. Patent #6204645</td>
<td>Battery charging controller for photovoltaic array using stationary battery and PWM to provide a constant load</td>
</tr>
<tr>
<td>U.S. Patent #6677730</td>
<td>Device and method for pulse charging a battery using PWM for photovoltaic applications.</td>
</tr>
</tbody>
</table>
## Applicable Standards

<table>
<thead>
<tr>
<th>Relevant Standard</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>IEC 62124</td>
<td>Photovoltaic (PV) stand-alone systems Design verification</td>
</tr>
<tr>
<td>IEC 61173</td>
<td>Overvoltage Protection for Photovoltaic (PV) Power Generating Systems</td>
</tr>
<tr>
<td>IEEE 1013</td>
<td>Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems</td>
</tr>
<tr>
<td>IEEE 485-1997</td>
<td>IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications</td>
</tr>
<tr>
<td>UL 2202</td>
<td>Electric Vehicle Charging System Equipment</td>
</tr>
<tr>
<td>UL 2231-1</td>
<td>Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: General Requirements</td>
</tr>
<tr>
<td>UL 2231-2</td>
<td>Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems</td>
</tr>
</tbody>
</table>

IEC- International Electrotechnical Commission
PREVIOUS KNOWLEDGE APPLICATION

- What is new with our project?
  - All of these systems will be combined to charge a vehicle battery
  - Utilization of battery to battery charging
RENEWABLE ENERGY

- Photovoltaic (P.V.) Energy
  - Provide sufficient energy to charge the mobile battery given 1.470 sun hours per day
    - May simulate some power with D.C. power supply
  - Plan to use Kyocera KC50T
    - High Efficiency: > 16%
    - Max Power: 54W
    - Competitive Cost
RENEWABLE ENERGY

- Wind Energy
  - Provides 1.2 kWh/day at a height of 50m
    - May simulate some power with D.C. power supply
  - Plan to use Southwest Wind Power Air-X
    - Start up wind speed: 7 M.P.H.
    - Rotor Diameter: 46 in.
    - Max Power: 400W @ 28 M.P.H
    - Vout= 24VDC
    - Competitive Cost
**Stationary Battery Charger**

- Integrates wind and P.V. energy to charge stationary battery
- Must accept max input values
  - Voltage: 24V
  - Current: 42A
- Output specifications dependent on stationary battery
- Charges stationary battery to maximize life
- Charging Scheme to be determined
- Monitors voltage and current characteristics of renewable energy and stationary battery
**Stationary Battery**

- Stores renewable energy to maximize energy collection when mobile battery is not charging
- Reduces mobile battery charge time
- Capacity needed determined by:
  - What is practical from cost standpoint
  - Stationary battery decay vs. mobile battery
  - Must be at least 180Wh
- Battery chemistry to be determined
# Stationary Battery

- Possible battery choices

<table>
<thead>
<tr>
<th></th>
<th>Optima Lead Acid</th>
<th>Li-Ion</th>
<th>Ni-CD</th>
<th>Ni-MH</th>
<th>Sealed Lead Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature Range (C)</strong></td>
<td>130 to -30</td>
<td>50 to -20</td>
<td>45 to -40</td>
<td>50 to -20</td>
<td>60 to -40</td>
</tr>
<tr>
<td><strong>Calendar Life (years)</strong></td>
<td>?</td>
<td>2 to 5</td>
<td>2 to 5</td>
<td>2 to 5</td>
<td>2 to 8</td>
</tr>
<tr>
<td><strong>Max Charge Cycles</strong></td>
<td>300+</td>
<td>1000+</td>
<td>300 to 700</td>
<td>300 to 600</td>
<td>250 to 500</td>
</tr>
<tr>
<td><strong>Discharge Profile</strong></td>
<td>Flat</td>
<td>Slope</td>
<td>Flat</td>
<td>Flat</td>
<td>Flat</td>
</tr>
<tr>
<td><strong>Self Discharge Rate @ 20C (% /mo)</strong></td>
<td>Very Low</td>
<td>2</td>
<td>15 to 20</td>
<td>15 to 25</td>
<td>4 to 8</td>
</tr>
<tr>
<td><strong>Memory Effect</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Ability to Trickle Charge</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Charging Characteristic</strong></td>
<td>2 stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Deep Discharge</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Relatively Quick Charge</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Constant Voltage Or Current Charge</strong></td>
<td>Voltage</td>
<td>Voltage</td>
<td>Current</td>
<td>Current</td>
<td>Voltage</td>
</tr>
<tr>
<td><strong>Relative Expense/ Capacity</strong></td>
<td>Cheap</td>
<td>Expensive</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Cheap</td>
</tr>
<tr>
<td><strong>Approx Expense (dollars)</strong></td>
<td>150</td>
<td>&lt; 600</td>
<td>300</td>
<td>350</td>
<td>80</td>
</tr>
</tbody>
</table>
STATIONARY BATTERY

- Li-Ion Eliminated
  - No Trickle Charge
- Sealed Lead Acid Eliminated
  - Low charge cycles
- Ni-Cd eliminated because similar to Ni-MH
  - Ni-MH has less memory effect
  - Ni-MH has higher energy density
- Optima Lead Acid vs Ni-MH
  - Optima
    - less charge cycles
    - significantly lower cost
    - no memory effect.

- Conclusion
  - Trade off between charge cycles and cost
  - Will probably choose Optima Lead Acid battery
MOBILE BATTERY CHARGER

- Accepts energy from stationary battery
- Must accept max input values based on stationary battery specifications
- Must be capable of outputting
  - Voltage: 14.9V
  - Current: 4.8A
- The mobile battery charger shall be capable of charging the mobile battery within at least 12 hours
MOBILE BATTERY

- Panasonic LC-RA1212P for Gaucho
  - 12V lead-acid battery
  - Rated capacity: 12Ah
- Minimal charge time
  - 2 hours 39 minutes
- Maximum battery life
  - 2-8 years
  - 250-500 charge cycles
- Constant Voltage Charge
POWER CONTROL SYSTEM

Select Menu
Keypad

Max Battery Life
(On/Off)

Min. Charge Time
(On/Off)

Emergency Charge

Microcontroller System

Battery Charging
(On/Off)

Percent Battery
Full

Time Remaining

Liquid Crystal Display

Power Control System
POWER CONTROL SYSTEM

- Power control system switches charging modes of mobile battery charger
- Three modes of charging
  - Maximum battery life
  - Minimum charge time
  - Emergency charge (Extended Objective)
- Monitors voltage and current characteristics of stationary battery and mobile battery
- Operational between 0C and 45C for battery protection
**Power Control System**

- Power control system is user interface
- Keypad input
  - User selects mode of charge
- L.C.D. output
  - Battery charging indicator
  - Battery charge percentage indicator
  - Time remaining until battery charged indicator
POWER CONTROL SYSTEM SOFTWARE

- Microcontroller software necessary for user input/output and switching charger modes
- Stationary battery charger flowchart:
MOBILE BATTERY CHARGER FLOWCHART

Start

Determine State of charge of the mobile battery

Is mobile battery charged?
  Yes
  Display that mobile battery has finished charging
  No
  Display that mobile battery is charging

Is max life mode active?
  Yes
  Stationary Battery Current and Voltage Information
  No
  Adjust PWM to charge mobile battery for maximum longevity

Stationary Battery Current and Voltage Information

Adjust PWM to charge mobile battery for maximum longevity

Calculate Percent Charged/time left to charge

Key:
- Primary Objective
- Extended Objective (if time permits)

Complement Renewable Sources with A/C power (100% if emergency charge mode)

Charge mobile battery
# System Datasheet

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun Hours</td>
<td>1.47</td>
<td>--</td>
<td>KWh/(m^2*day)</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>7</td>
<td>28</td>
<td>MPH</td>
</tr>
<tr>
<td>Stationary Battery Capacity</td>
<td>180</td>
<td>--</td>
<td>Wh</td>
</tr>
<tr>
<td>Mobile Battery Charger Output Voltage</td>
<td>14.5</td>
<td>14.9</td>
<td>V</td>
</tr>
<tr>
<td>Mobile Battery Charger Output Current</td>
<td>--</td>
<td>4.8</td>
<td>A</td>
</tr>
<tr>
<td>Temperature</td>
<td>0</td>
<td>45</td>
<td>C</td>
</tr>
<tr>
<td>Time for mobile battery to charge</td>
<td>2.7</td>
<td>12</td>
<td>Hrs</td>
</tr>
</tbody>
</table>
ANALYTICAL CALCULATIONS

- **Load Calculation**
  - Capacity 12V*12Ah=144Wh
  - 144 W*3600 sec*1.25 = 648000 J

- **Solar Power Calculation**
  - Efficiency*Area*Sun hours*3600 seconds
  - Maximum Spec 54W=194400 J/hour
  - Worst Case for Chicago = 285768 J/day

- **Worst Case Number of Solar Modules**
  - 648000 J/285768 J= 2.267 P.V. Modules
ANALYTICAL CALCULATIONS

- **Load Calculation**
  - Capacity 12V*12Ah=144Wh
  - 144 W*3600 sec*1.25 = 648,000 J

- **Wind Power Calculation**
  - @ 12 M.P.H. 1.2 kWh/day generated
  - @ 12 M.P.H. 4,320,000 J/day generated
  - Average in Peoria, IL 14.3-15.7 M.P.H.
## Equipment List

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

Power electronics will be purchased after schematic finalization.
Gantt Chart

Days:  Blake    Phil
QUESTIONS?