Control of a Hybrid Energy System

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Outline

- Introduction
- Background
- Problem
- Design Methodology Research
- Design Overview
- Results
- Conclusions
- Recommendations
Introduction

- Effective way to combine multiple renewable energy sources
- What is a hybrid energy system?
  - Wind
  - Solar
  - Tidal
  - Micro-Hydro
  - Etc.
Introduction

Today's Hybrid System

UNSTABLE AC and/or DC Power …

Solar Panels

Wind Turbine

Grid Power

Requires STABLE AC Power

Cabin or Home or Boat Electrical Panel

Net Metering

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Introduction

- Small wind less than 10kW
  - My research deals with micro small wind up to 1500 watts and 1000 watts of solar
  - Most common for cabins, boats, peak shaving systems in residential locations, and total power production in developing nations
Background

- Increasing demand for alternative power
  - Energy shortage
  - Power distribution problems
  - Kyoto Protocol
  - Rising cost of fossil fuel
  - Incentives
  - Green Movement
Background

Current solutions

- Controllers that perform one function
- Controllers that can do both wind and solar
  - Can only combine small amount of solar
  - Not entirely reliable
  - Will only work with one brand of turbine
  - Typically wind companies have built in some solar control
  - Solar companies have no wind control
Problems

- Many technical issues with hybrid systems
  - High variability in resource, e.g. wind, sun
  - Many components required
  - “Hybrid systems have a 65% or more failure rate, with failures due to components failing, poor maintenance, . . . .” (Vaughn C. Nelson, 2002)
  - Lack of monitoring of system
  - History logging
  - Remote communications
Design Methodology

- Goals to achieve
  - Reliability
  - Efficiency
  - Integration
  - Component number
  - Flexibility
  - Functionality
  - Convenience
Design Methodology
Design Methodology

- System design overview
- Design of each system block
- Implementation
- Testing
- Integration
- System testing
Design

- ARCS (Autonomous Renewable Control System)
Design - LDC

- Load Diversion Control
  - Charge lead acid batteries
  - Keep wind turbine under control
    - Load at all times
  - Integrate solar energy
Design – AC Rectifier

- Three phase full bridge rectifier
Design - Motherboard

- Data acquisition
- Storage
- User interaction
- Solar control
- LDC interaction
Design - Motherboard

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Design - Motherboard
Design – Sensor Pack

- Measures current of all components of system
Design - Safety

- Safety systems are critical for all electrical systems
  - Breakers for over current protection
  - Circuitry for voltage protection
Design - Case
Design – Solar Algorithm

- System Status
  - Both Solar and Wind?
    - Yes
      - Is Solar Connected?
        - Yes
          - Is voltage >95% battery capacity AND wind current >0?
            - No
              - Reconnect Solar
            - Yes
              - Disconnect Solar
        - No
          - Is voltage <90% battery capacity OR wind current stable at 0 amps?
            - No
              - Reconnect Solar
            - Yes
              - Disconnect Solar
  - No

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Design - Software

- Control algorithms
- User interaction
- Graphical user interface for unit and PC
- Firmware/Software
Test System

- Southwest Windpower - Whisper 200
- Evergreen Solar – two 110 watt panels
- Xantrax – SW5548 inverter
- Nautilus lead acid batteries
**Results**

- **Average expected monthly production**

<table>
<thead>
<tr>
<th>Component</th>
<th>Production (kWh/yr)</th>
<th>Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV array</td>
<td>328</td>
<td>13%</td>
</tr>
<tr>
<td>Wind turbine</td>
<td>2,266</td>
<td>87%</td>
</tr>
<tr>
<td>Total</td>
<td>2,594</td>
<td>100%</td>
</tr>
</tbody>
</table>
Results

Wind Speed

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Results

Wind Power (Raw Data)

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Results

Power and Wind December 2006

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Results

- Power Curve Measured vs. factory
Results

- Solar Data
Results

- Wind Power and Battery Power
Results

- Track power production, cost savings, GHG emission savings
Conclusions

- Effectively combined wind and solar
- Increased power curve of wind turbine
- Allowed significant addition of solar power
- Increase reliability
- Tracked history and made data portable
- Increase in safety and usability
Conclusions
Recommendations

- Interaction with the grid
- Different turbines and solar arrays
- Multiple control schemes
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Thank you

Questions/Discussion