Current Plans for the ARA Autonomous Renewable Power (AARP) Station
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- Goals
- Turbine Selection
- Sites
- APS Block Diagram
- Modeling
- Siting Plans
- Monitoring Comms
- System Health Monitor
- Static

Component documentation is gathered at http://www.idl.ku.edu/ARA/AARPS/Documents
ARA AARPS Goals

1. 300W dc power (total) to be provided to 3 ARA clusters, communications, and monitoring systems.
2. Live time > 97%.
3. Deployment by 2 persons.
4. Serviceable by 2 persons.
5. Extensible by incremental addition of components.
6. Service interval >= 1 year.
7. Replacement interval >= 10 years.
2011 ARA AARPS Goals

1. Test performance of 3 different turbines at Pole: robustness, power curve, deployment.
2. Determine wind profile (alpha) in order to optimize tower height.
3. Test performance of a Photovoltaic (PV) panel.
4. Attempt to quantify parameters related to performance: heat losses, temperatures, wind speeds and directions, etc.
5. Develop better sensing techniques for monitoring power inputs and outputs.
6. Compare ultrasonic anemometers with the standard RM Young propeller anemometer.
7. Develop an equipment box with adequate thermal insulation and emi shielding.
8. Improve understanding of the effects and possible mitigation of static buildup.
9. Develop deployment procedures.
## Comparative figures – we will test 3

<table>
<thead>
<tr>
<th>Turbine</th>
<th>Cut-in (m/s)</th>
<th>Power (@8m/s) Manufacturer's data</th>
<th>Weight (kg)</th>
<th>Diam (m)</th>
<th>Turbine Cost</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerogen 6 (UK)</td>
<td>3.0</td>
<td>360</td>
<td>12.6</td>
<td>1.2</td>
<td>$1950</td>
<td>* Successful on plateau but too small.</td>
</tr>
<tr>
<td>Ampair 600 (UK)</td>
<td>3.3</td>
<td>515</td>
<td>16</td>
<td>1.7</td>
<td>$2900</td>
<td>* Successful on margin; probably too small.</td>
</tr>
<tr>
<td>Bergey XL.1 (US --Norman, OK)</td>
<td>3.3</td>
<td>713</td>
<td>39</td>
<td>2.9</td>
<td>$3600</td>
<td>* Used successfully on the margin.</td>
</tr>
<tr>
<td>Raum 1.5 (Canada – Sask)</td>
<td>3.3</td>
<td>650</td>
<td>37</td>
<td>2.5</td>
<td>$2790</td>
<td>* Manufacturer reports successful Arctic deployments</td>
</tr>
<tr>
<td>Kestrel e300i (South Africa)</td>
<td>2.5</td>
<td>471</td>
<td>75</td>
<td>3</td>
<td></td>
<td>* Recommended for robustness; many in U.S.</td>
</tr>
<tr>
<td>Windsport 1.5 (Spain)</td>
<td>2.5</td>
<td>1400</td>
<td>143</td>
<td>3.6</td>
<td></td>
<td>* Looks impressive, but heavy. Many in Europe.</td>
</tr>
<tr>
<td>Hummer 1kw (China)</td>
<td>3</td>
<td>760</td>
<td>15</td>
<td>3.1</td>
<td></td>
<td>* Looks robust; many in China.</td>
</tr>
<tr>
<td>Xzeres 2.5kw (US)</td>
<td>2.5</td>
<td>1600</td>
<td>190</td>
<td>3.5</td>
<td>$25,000</td>
<td>* Based on AWP; under test by NREL at Pole in 2010.</td>
</tr>
<tr>
<td>Proven 7 (UK)</td>
<td>2.5</td>
<td>1600</td>
<td>190</td>
<td>3.5</td>
<td></td>
<td>* Recommended, but too big?</td>
</tr>
</tbody>
</table>
Manufacturers’ Power Curves

Notes:
1) Probably all at sea level.
2) Large “grain of salt” required,
Wind (profile from Data)

Shear Factor - $\alpha$
$f(\text{surface roughness})$

To Comms Antennas

Long-term AARP Station goal

Photovoltaic Panels
Rated: 212W
Efficiency: 14%

Heat loss $f(\text{insulation & leakage})$

Power Out

$\leq 200\text{W} @ 24V$

External Dump

System Health Monitor

Diodes

Surface Processing & Comms

Power Control

$\sim 5\text{W}$

$\sim 10\text{W}$

$<1\text{W}$

$\sim 1\text{W}$

SLA Batteries

Heat Pad

As needed

Flux $f(\text{season, declination})$
$\text{Absolute Magnitude unknown}$

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## Inputs for System Model to determine Live Time / Battery Requirements

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Curves</td>
<td>Taken from manufacturers; must be verified.</td>
</tr>
<tr>
<td>Wind profiles</td>
<td>Acquired from AWS, Met office; will be measured in coming season.</td>
</tr>
<tr>
<td>Tower Height</td>
<td>$S/S_0 = (H/H_0)^a$ – $\alpha$ estimated at 0.002; will measure 01/2011.</td>
</tr>
<tr>
<td>Photovoltaic output</td>
<td>Depends on solar flux. Output to be measured during coming season.</td>
</tr>
<tr>
<td>Power Requirements: ARA</td>
<td>Now estimated at 200W.</td>
</tr>
<tr>
<td>Power Requirements: SHM &amp; Comms</td>
<td>Estimated at 10W. To be measured.</td>
</tr>
<tr>
<td>Power losses in the enclosure</td>
<td>TBD</td>
</tr>
<tr>
<td>Number of batteries per APS</td>
<td>TBD from this season’s testing</td>
</tr>
<tr>
<td>Heat losses from the equipment</td>
<td>To model from R value and determine from coming season’s measurements.</td>
</tr>
</tbody>
</table>

The University of Kansas
Instrumentation Design Laboratory
Computed Wind Speed as $f(\text{height, } \alpha)$

- $\alpha=0.2$
- $\alpha=0.02$
- $\alpha=0.002$

Relative Wind Speed vs. Relative Height
2010-11 Site 1
Tower Tests

Goals:
1. Erect 40-60’ tower with 2 people + winch + snowmobile.
2. Measure wind speed at multiple heights for 4-6 days.
3. Acquire data in the ICL.
4. Determine best tower height.

The Tower height for this test is subject to review. The most useful data could well be below 7m.

15m lattice tower (10’ sections)

Anemometers at 10’, 25’, and 40’.

Prevailing winds

Reinforced POE-enabled ethernet, ~ 150m

ICL ground reference for static measurements.

Equipment box, eventually buried.

Plywood base 3-4’ below surface

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Goals:
1. Erect 40-60’ tower & Bergey XL.1 turbine with 2 people + winch + snowmobile.
2. Erect frame and photovoltaic panels.
3. Install batteries, health monitors.
4. Install Monitoring Comms

Anemometer(s) (wind speed, direction, and possibly temperature and pressure.) Will probably test ultrasonic devices as well.

Antenna (to look for turbine noise.)

Antenna monitoring method not finalized.

ICL ground reference for static measurements.

LMR-400

1 PV panel, rated at 210W

Reinforced POE-enabled ethernet, ~150m

ICL

Dummy Load

Equipment box, eventually buried.

Plywood base 3-4’ below surface
Goals:
1. Erect 7-15m tower & Turbine 2 with 2 people + winch + snowmobile.
2. Install batteries, health monitors.
3. Install & test Monitoring Comms via Zigbee protocol.
4. Connect to SJB for redundant comms.

2010-11 Site 2

Prevailing winds

Omni Antenna for Zigbee comms

Anemometer(s) (wind speed, direction, and possibly temperature and pressure.)

7-15m lattice tower (10' sections)

Plywood base 3-4' below surface

Equipment box, eventually buried.

Dummy Load

SJB String 22
Goals:
1. Erect 15m tower & Turbine 3 with 2 people + winch + snowmobile.
2. Install batteries, health monitor.
3. Install Monitoring Comms; test mesh operation.
4. Test all systems

2010-11 Site 3

- Prevailing winds
- Antenna for Zigbee comms
- 7-15m lattice tower (10' sections)
- Anemometer (wind speed, direction, and possibly temperature and pressure.)
- Plywood base 3-4' below surface
- Equipment box, eventually buried.
- Dummy Load
Reinforced plywood base.

7-20 m lattice tower (10' sections)

1 of 4 Kevlar guy ropes

Deadman anchor
Tower installation

Depth and size of deadman anchor TBD
Anchor for base TBD
Hinged tower mount supplied with tower (includes Gin Pole)

Distance > tower height

Gin Pole
Reinforced plywood base

Tie winch to a deadman or to a vehicle.

Procedures for Raum lattice tower install:

For Raum monopole:

Procedures for a Bergey tower:
All corners sealed, inside and outside of the insulation. Masonite inside the insulation. Full insulation all 6 side with a gasket on the lid and multiple clips. All penetrations in the same area. Penetrations use gaskets. EMI sealed.

For either option, the box will be carefully insulated, with Nanopore Vacuum Insulation Panels (R=8) or Dow Blue Board (R=6.5) or Polyisocyanurate (R=7-8).

(R is specified for 1”)

Equipment Box

OR

Plywood box, sized according to needs.

Hardigg Mobile Master 24
Comms Summary

960 MHZ Zigbee (mesh)  

SJB String 22

Quad in IC Surface cable

Reinforced POE-enabled ethernet, ~50m to ICL

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System Health Monitor

Static Measurement
- Anemometers: wind speed & direction (1-3) & Temp. (pressure?)
- TBD

Inside air Temperature
- Semicon. sensor

Heat Pad Temperature
- Semicon. sensor

Turbine current
- Hall-effect Sensor
- Voltage Divider/Condition'rs

Turbine voltage
- Comms (Zigbee/Ethernet/SJB)

$\geq 1$GB Flash Memory, removable

$\frac{n}{2}$ Battery Monitors
- Battery bank voltage
- Semicon. sensors
- Temperature on each battery

Common

Photovoltaic currents (3)
- Hall-effect Sensors
- Voltage Dividers/Condition'rs

Photovoltaic voltages (3)

Serial
Information about static (much is obvious). Note that nearly every reference opens by saying that the phenomena are not well understood.

* Wind-related noise is observed at AURA DRM's at both 250m and 1400m. The source remains unknown.
* Many anecdotal Polar stories are told about static and arcing; most installations avoid damage and interference by maintaining a robust common.
* A source of static build-up on structures is likely the triboelectric effect of snow/ice particles impacting other materials. This is observed in: 
  - Aircraft: http://www.smartcockpit.com/data/pdfs/flightops/meteorology/Precipitation_Static.pdf
  - Skis: http://www.dominatorwax.com/snowfriction.html
  - And electronic communication in snowstorms.
* There is also sizable electrostatic buildup in blowing snow. This could be the source of the observed noise. See http://www.idl.ku.edu/ara/APS/ Documents/ESD/snow-electrostatic.pdf

* If the noise arises from ESD, it would probably come from structures. Normal methods of mitigation revolve around good grounding (unavailable at Pole.) It would also be reasonable to expect that changing the contact material would help (see the triboelectric series: http://amasci.com/emotor/tribo.html). A coating could help.
* Aircraft mitigate by making sure all conductive structural components share a robust common and then bleed off static through pointed structures on the wings. Their biggest concern is ESD between different components of the plane.

* Conclusions:

1) We have not found a way to measure or reduce static on structures in the absence of a ground reference. Static on structures might be mitigated with a coating. However, we are not set up to apply coatings or to run control experiments.

2) We expect that the noise experienced currently arises from the surface (blowing snow) and is unrelated to a turbine, but we want to see if the turbines add to that.

3) Work is underway at Nebraska to devise a way to measure static buildup.
Status

* We are nearly prepared to order turbines. The visit to the AWEA (American Wind Energy Association) exposition 24.05.10 added a few things to check.

* Tower selection is not complete. The heights are likely to be modified downward. Some interesting alternatives have been provided.

* We are consulting about the base for the tower and securing the guy wires. Jeff Cherwinka has provided some insight from IC experience. Advice will be welcome.

* See previous page about ESD. We do not have a plan to mitigate possible ESD this season.

* The Sensor boards for measuring voltage and currents from turbines and PVs are in design, and the sensor board for transmitting wind speed and direction are beginning to be designed.

* Some testing has been done with the low-power/low-speed comms. We have equipment in house. Some of the monitoring equipment is complete.

* By the end of the month, we will have ordered most components.

* After receiving the turbines we will need to change out most bearings and grease. (Raum will do theirs for us.)

* By mid July, anechoic chamber tests will be completed on the turbines, and we will have tested the erection of a tower.