MET_Power_Status_2016 Documentation

Release 1

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Contents:

CHAPTER 1

Power Summary

In 2015 a multi-year upgrade was completed at primary meteorological sations at the HJ Andrews Experimental Forest. Prior to the upgrade, stations used a small number of old, Edlog based loggers to link a large array of sensors using an extensive network of cables. This centralized data transfer within each station.

The upgrade introduced a dispersed digital network where multiple loggers independently connect to the network at each site. However, adding independent loggers at each site, each with independent radios, created an increased demand on infrastructure. In the winter of 2015/2016 the low sunlight conditions in combination with increased demand lead to station crashes.

My assessment of the stations as a whole is that there are not enough checks and controls to ensure the integrity of the system of physical components paired with the digital network. Power is limiting, but increasing power alone will continue to leave the station vulnerable to crashes. Further, a large push to increase power is impractical, because the physical infrastructure is dispersed within each site, requiring separate upgrades for: 1)towers, 2)shelters, 3)stand alone rain gauges, 4)aspirated fans

1.1 Key System Problems

The key issues all stem from added components that are unregulated; their power usage is not monitored, and they draw continuously, whereas most sensors draw power for a fraction of each logger scan.

1.1.1 Unknown System Current

There is currently no tracking of system power (Watts) or current (Ampre). This makes it difficult to know if the system is functioning properly. It is especially hard to identify when current usage exceeds charging. It also makes it difficult to assess battery health or changes in panel efficiency.

1.1.2 Limited or No Battery Protection

There are few Low Voltage Disconnects (LVD's) on batteries, and no digital or manual shut offs for any part of the met station. This allows stations to fully discharge batteries. Once fully discharged, they cannot be recharged once solar power returns. Therefore, the station will not regain power until the batteries are replaced, even during sunny periods. This has the potential benefit of logging data until the last possible moment, but ruins the batteries, which has a high monetary cost.

1.1.3 Fan Status

The largest single draw is the 43502 aspirated radiation shield. At all stations these have an independent power supply, so the draw does not impact other components. However, the current to operate the fan is 120% to 190% of the power budget for the loggers. Estimates suggest that 4 - 6 months per year, there is not enough solar power to fully support daily fan current, and that batteries will only last 6 - 9 days. It is likely from Oct through March that the fan turns off when the sun isn't out. This could cause battery damage that would prevent charging even in summer. However there is no way to verify when the thermistor is being aspirated. This is a data quality issue that should be monitored.

Due to the high draw it is important to have the ability to shut the fan off when power supplies are low.

1.1.4 Network Connectivity

Network connectivity is the second largest draw on the power system. The radios and NL116's consume from 75% to 95% of current at each station daily, plus an additional 10% loss in conversion from 12v to 24v. However, the radios are only transmitting for a fraction of the time for which they are running. This is wasted power.

Without the ability to turn the radios off, there are no options for operators when power is low. It is important to provide multiple options to allow operators to address a variety of expected or unforeseen problems.

1.2 Mid-Priority Problems

- Poor solar sites (low duration and intensity)
- Vegetative overgrowth and shading
- **Reduced solar panel efficiency**
  - ~1% per year
  - solar panel ages are unknown
- **Inadequate charge controller placement**
  - use of charge controllers outside of designed temperature range
  - use of unsealed charge controllers in moist environments and exposed to moisture vented from batteries.
  - exposure to overheating (low ventilation, proximity to batteries)
  - exposure to corrosive battery acids and gases
- **Use of PWM charge controllers**
  - Inefficient in cold weather
  - Inefficient in indirect light
- **Degraded wiring**
  - damaged and disintegrated insulation
  - exposure to sunlight and moisture

1.3 Proposed Improvements

1. Installation of shunts to track and monitor system power usage.
2. **Program logger to control power to fans and radios.**
   (a) Set a low power shut off.
   (b) Schedule radio transmitions for discrete periods of time.
3. Provide manual power shut offs to all components.
4. **Improve charge controllers:**
   (a) Prioritize removal of charge controllers without LVD.
   (b) All replacement charge controllers will be MPPT for cold temperature and low light efficiency.
   (c) Use available enclosures to house and protect charge controllers separately from batteries.
5. Where possible, all updated portions should use electrical conduit to protect wiring.
6. Remove or reduce vegetation that blocks solar panels.
7. In some specific cases, solar panels should be moved to new locations, requiring some reconfiguration.

CHAPTER 2

Station Status

2.1 System Demand

A round of upgrades was finished at benchmark meteorological stations in 2015 with the goal of promoting data accessibility, allowing connectivity to data loggers, and improving measurement methodology, while ensuring data security. Network connectivity was a large part of the addition. This allowed multiple loggers to connect to a network, doing away with long cable connections within stations. It also allows for greater access and control of logger function. Another large addition was aspirated radiation shields which increase measurement accuracy. Below, the power demands of this new network are assessed in two parts: 1) the current requirements of the system, 2) the power available to the system. Systemic liabilities to the power supply are discussed, along with some possible solutions.

2.1.1 Electrical Draw

Estimation Methods

Daily Current vs. Peak Current

The system draw or current is a measure of the flow of electrical charge (Ampere). Inherently, this is a rate that fluctuates as more or less electricity is required. For example, as components turn on and off. To calculate the amount of charge used, the rate must be multiplied by the length of time that the component is turned on.

Below, the current is discussed as peak current or peak draw in Amps (A). This represents the highest rate at which the the system will draw a charge. This is an important factor in sizing wiring and other components, and can have a large effect on how long a battery can provide power.

Below, the daily draw is also discussed, in Amp hours (Ah). Since different components are turned on for different amounts of time, the peak current does not represent the amount charge required. The daily draw provides an aggregate estimate of total draw which accounts for how long each component is turned on, and what the current is for that component.

Campbell Model

Campbell Scientific (CSI) provided an Excel macro [1] to estimate system demand and solar power source. Components and sensors sold by CSI can be directly input, and unique components can be manually entered. This tool was used to produce general estimates of charge required by the met stations. To add custom components, the following specifications are required:

[1] CSI PowerBudget13_v1 `Spreadsheet` , web how to

1. Active Current (A)- current when turned on
2. Quiescent Current (A)- current when turned off
3. Active Time/Scan (mSecs)

When these specifications were not available "ball park" estimates were used. Below is a list of custom parameters input:

- MET stations are on 15 sec scan, which is not one of the provided options. 10 sec is used instead. This inflates estimates.
- **Radios are always on. Active time set to 10,000- info from Adam Kennedy**

  Exception Xtend-NEMA tests connection for 1 sec every 16 sec, and downloads for 1 min per hour
- **Radio power is an average from independent tests provided by Adam Kennedy in Watts**
  - $I_A = \frac{P_W}{V} = \frac{7}{24}$
- **CSI model CSAT3 was substituted for the WindObserverII Ultrasonix Anemometer**
  - the WindObserverII- 40mA active, no quiescent listed
  - CSAT3- 67mA active and quiescent
- **LT420 Float Gauge**
  - Active time set as 50 mSec active per scan. No value listed in manual
  - Active current set to 20mA. Factory calibration specified as 20mA
  - Quiescent current set as 10% of active current
- The NL115 was substituted for the NL116. Estimates include draw of both ethernet mode and card mode separately
- **Current to activate the pump switch at standalone rain gauges was defined as 1.6mA by CSI (Bruce)**
  - Active time was set as 210 mSec = $\frac{15cycles*\frac{2min}{cycle}}{24hr} = 0.021 * 10,000mSec$
- When the station had more devices than the macro allows, components that drew < 1% of the daily current were removed

The CSI format was mimicked in a separate spreadsheet. This independent power budget [2] consistently estimates less than the CSI macro by 16% for shelters and 24% for towers. However, by including a fuller suite of sensors, the contribution of individual components relative to each other provides useful insight.

Draw Summary

Here is an overview of common system components using CSI estimates. Each station will be further discussed individually. Estimates are based on station configuration at the beginning of 2016. Aspirated fans have independent power supplies and are listed separately.

[2] Independent Power Budget `Summary Spreadsheet`

Station	System Daily (Ah)	System Peak (A)
CENT Shltr	3.23	0.112
CENT Twr	12.06	0.419
UPLO Shltr	6.91	0.240
UPLO Twr	13.19	0.458
VARA	10.38	0.361
VAN Twr	12.43	0.432
ASP Fan	14.63	0.508

The highest daily draws result from components that are on for long periods of time. These components account for disproportionate amounts of the system current demand. Below is a list of the components with the highest daily draws, taken from the independent spread sheet.

Component	Daily (Ah)	Peak (A)
ASP Fan	12.19	0.5
Radio- Tranzeo	7	0.292
Radio- Nano	3.98	0.166
Sonic Anemometer	0.96	0.04
Radio- XtendNEMA	0.73	0.11
NL115 Card	0.55	0.023
NL115 Ethernet	0.48	0.02
Xantrex C35	0.31	0.013
SR50A	0.26	0.25
SunSaver 10	0.192	0.008

Note: Radios (**except NEMA**) require a conversion to 24v. The current provided above is after the conversion to 24v. This underestimates the system draw because >10% of power is lost during conversion.

The highest draw is from components that run continuously. While the aspirated fan must run all the time, the radios are only transmitting for a fraction of the time that they are powered. For example, extend NEMA takes a minute to download an hours worth of data. Powering the device while idle is wasted energy.

Also, note that the Xantrex charge controller uses almost double the current of the SunSaver. It is important to assess efficiency when buying components.

2.1.2 Power Supply

Each station has a different configuration of solar panels and batteries, ranging in size, age, and number. These will be discussed individually for each site, but a broad overview is presented here. Stand alone rain gauges are not discussed. Their structure has been static for many years. They have the oldest solar panels, but seem to work, and as a result, they are lower priority at this time.

Now, with estimates of the current required to run the system, it is important to look at the present power supply and storage. Power supply is determined by solar panel rating, reduction in solar panel function with age, and available sunlight. Storage is determined by the battery bank. During winter sunlight has shorter duration and intensity. Under these conditions, solar panels produce small amounts of power, requiring more solar panels to create enough energy. This must be balanced against the size of the battery bank for storing energy during periods when solar panels are ineffective.

Solar Power Production

At a minimum, solar power must generate enough current to exceed daytime demand by enough to recharge batteries from night time draw. Below is the sum of solar panel wattage at each site and total daily power requirements (in Watts hours).

Station	System Daily (Wh)	Solar Panel(W)
CENT Shltr	38.2	50.2
CENT Twr	144.72	200
CENT ASP	**175.56**	**100**
UPLO Shltr	82.9	240
UPLO Twr	158.28	260
UPLO ASP	**175.56**	**100**
VARA	124.56	131
VAN Twr	149.16	210
VAN ASP	**175.56**	**52.6**

Each solar panel specifies reference conditions needed to produce it's rated wattage. While some of the oldest panels differ slightly, most solar panels require 1000 W m^{-2} to produce their rated power. For stations where the solar panels meet or exceed estimated power requirements, only 1 hour of sunlight is required at this intensity. If the rating is less than estimates of power needs, than more time is needed at the specified intensity.

It is clear from this quick overview that the current allocation of solar panels is not proportional to power needs. The power requirements of aspirated fans are as much as 1.75 - 3.5 times more than the rating of their solar panels. During much of the year, sites do not cumulatively receive 1 kWh of sunlight a day, indicating that the fans are not fully powered. UPLO shelter, however, has solar panels rated at 3 times it's daily power needs.

Note: Batteries are not 100% efficient. If 10 Wh are drawn from a battery overnight, it may take >10Wh to restore the charge to the battery the next day.

Also

Solar panels loose an average of 1% of capacity per year [3]. The oldest solar panels may produce approximately 20% less than rated.

Battery Bank

The minimum requirement for the battery bank is that it be large enough to supply current during nighttime hours. During winter the batteries must supply more than 0.75 of the daily current requirement. During storm cycles, they may need to supply charge for longer.

Stations nearly exclusively use `USBattery 1800 XC2`.

Station	System Daily (Ah)	Battery Bank(Ah)	Days to 30% DOD	Day to Total Discharge
CENT Shltr	3.23	416	>14	48.8
CENT Twr	12.06	624	10	36
CENT ASP	14.63	416	**6**	**17.4**
UPLO Shltr	6.91	416	11	36.9
UPLO Twr	13.19	624	10	32.6
UPLO ASP	14.63	624	9	34.9
VARA	10.38	208	**4**	**12.4**
VAN Twr	12.43	1040	>14	73
VAN ASP	14.63	416	**6**	**17.4**

Bold values highlight stations with extremely low storage. These stations are unlikely to survive a single bad storm cycle without substantial solar panels.

Similarly to solar panels, batteries are not allocated proportionally to system draw. Aspirated fans have the highest draw, but have undersized battery banks, while several stations have oversized battery banks. Aspirated fans in particular don't have adequate solar panels to meet daily power needs, and have undersized battery banks. It is possible that

[3] `Jordan, D.C. and S.R. Kurtz.` 2012. Photovoltaic degradation rates- an analytical review. JA-5200-51664, NREL. Oakridge, TN.

these components regularly exceed their power supply, but they are unmonitored, so there is no way to confirm system draw, battery voltage, or whether they are turned on.

Note: Battery Ah need to be adjusted for temperature.

2.2 Environmental Conditions

2.2.1 Available Sunlight

It is important to determine if solar conditions at each site are adequate for the solar panels present. If lighting is only a fraction of the reference intensity, then an aggregate of multiple solar panels will be needed to provide enough power or the battery bank needs to be large enough to supply power until conditions improve. Available sunlight varies intra-annually with: day length, sun angle, and seasonal storms. It also varies inter-annually with climate.

Below is a distribution of solar intensity at each site based on pyranometer readings. Since the reference conditions for most solar panels is 1000 W m^{-2} (1 kW), the units used are kWh. Records begin with pyranometer installation at each site and go until 2015. Distributions are based on mean daily kWh per week for the entire record (i.e. summer and winter are graphed together). Mean monthly values for all sites are also displayed.

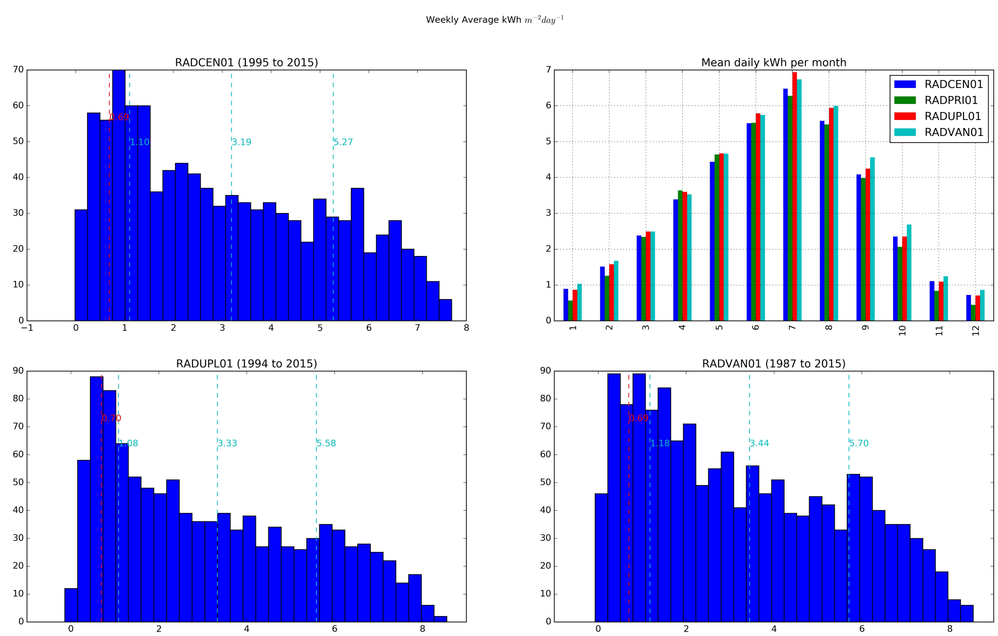


Fig. 2.1: Blue lines are drawn at the 1) mean - 1std, 2)mean, 3)mean + 1std. Red line represents 10th percentile

At most sites, in December and January mean daily light intensity is slightly less than reference conditions, however, average daily conditions exceed reference conditions for all other months. After accounting for this reduced output, the aggregate values of solar panel power must meet system needs, or the battery bank must be sized to compensate.

Worst Case Storm Cycle

In addition to expected seasonal variation, the power system needs to be sized for irregular long-duration storm events. While storm duration was not explicitly assessed, available sunlight can be used as a conservative estimate. Pyranometers underestimate sunlight during snow events, as they may become buried during the storm and remain undersnow for a period after the storm passes.

Across sites, **0.69 kWh per day** represents the 10th percentile worst week recorded. Displayed values are weekly averages: each value represents the total sunlight per week divided by seven. Tests were done to find the 10th percentile of sunlight at 1, 2, 3 and 4 week intervals. However, it was found that the worst 10th percentile of weeks always had less sunshine per average day than an average day in any 2, 3, or 4 week period. In longer periods, there was always a moment of sun that increased daily averages.

2.2.2 Temperature

Temperature is an important factor in electrical systems. Wiring, converters, and charge controllers all increase losses at increased temperatures. However, at colder temperatures lead acid batteries have effectively lower charges. Some equipment, such as charge controllers, are not even designed to operate at cold temperatures. It is important to include hottest and coldest temperatures when sizing equipment.

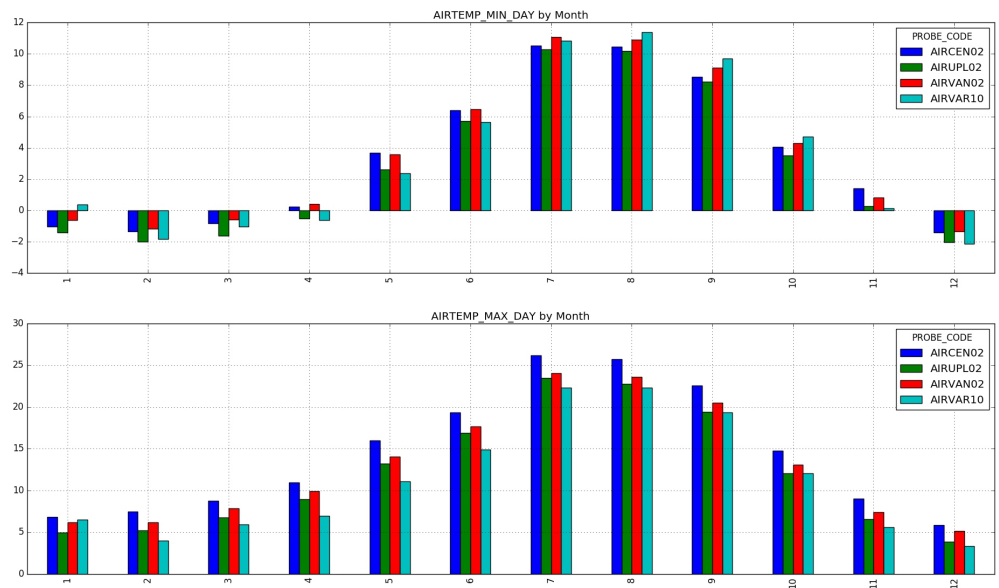


Fig. 2.2: Mean daily max and min temperatures (20 - 28 yr record)

2.3 Power Guidelines

The worst week experienced across sites can be expected to have 0.69 kWh of sunlight per day, assuming no blocking vegetation and correct panel orientation. Sunlight may stay only slightly above this level for 3 or more weeks. This means that the minimum solar sizing should be **daily power(Wh) draw / 0.69kWh.**

Additionally, batteries should be able to maintain during weeks where amounts of sun are below the 10th percentile due to snow cover, and short days. To survive 1 week with no solar power, without allowing the batteries to exceed 30% depth of discharge means the battery must sustain more than 70% of it's 20hr Ah rating, or **(daily Ah x 7 days) / 0.3** . Campbell Scientific uses a more conservative factor, replacing 0.3 with 0.21.

Currently, solar panel and battery placement do not match power requirements. Resources need to be reallocated so that power supplies are placed where there is a corresponding electrical demand.

CHAPTER 3

System Improvements

3.1 Systemic Problems

Many components of the MET stations are old, and undersized. However simply adding solar panels and batteries, will not reduce the chance of system failure and would easily exceed the budget. The present station design is built around production of data. However, it ignores the operation of the system that collects the data. This risks generating erroneous data and allowing the system to crash. It also means that power supply is often not where it is needed. The stations need to be designed to support the function of the system as a whole. It would be difficult to supply enough power to match current demand, but it is possible to maintain current function with a lower power requirement.

Key tenants of design are:

1. **Monitoring all devices**
    (a) Track system power generation and draw
    (b) Make it easy to identify system malfunctions
    (c) Make it easy to anticipate loss of power
2. **Provide redundant operations**
    (a) Multiple power sources (e.g. multiple charge controllers)
    (b) Multiple ways to restrict components (e.g. turn radios off)
    (c) Multiple data backups
3. **Protecting equipment from degradation**
    (a) e.g. proper cooling for charge controllers
    (b) e.g. controlled phase down of power usage when power generation is low
4. **Intelligently allocate power**
    (a) Careful monitoring allows power to be intelligently distributed to components that need it most
    (b) Monitoring can be used to trigger reallocation of power as conditions require

Example For example, 2015 a charge control went bad at UPLO. This overdischarged the batteries, ruining them. It also cut power to the logger, which stopped data collection and allowed the rain gauge to freeze. Better monitoring of power supply would have identified that there was a problem. A secondary power source would have kept the station running while the faulty controller was fixed. Redundant programatic and manual switches would have allowed high draw components such as radios to be disconnected, conserving power. A low voltage disconnect could have further protected the batteries. Finally, if the charge controller were stored in a dry, well ventilated area away from caustic battery gases, it may not have failed at all. This clearly demonstrates the need for system upgrades to focus not just on power, but on function.

Nearly 80% reduction in power needs can be achieved with changes to radio and power configurations. This eases the power requirements and allows focus to be directed at system liabilities such as:

- Monitoring power usage
- Providing manual and programmatic controls over power use
- **Improving charge controllers**
  - Add LVD's
  - Protect charge controllers from moisture and overheating
- Improving protection of degraded wiring

3.2 Proposed Improvements

Each station is uniquely configured and has special problems which should be addressed. Here I discuss large scale functional changes that apply to all of the met stations, and attempt to estimate the power savings and the monetary cost.

3.2.1 Monitor System Current

All loggers will have a shunt installed to track logger current. This allows close monitoring of system operations, battery depth of discharge, and number of battery cycles. Number of battery cycles is the strongest indicator of battery lifespan and number of Ah discharged is the only way to confidently measure depth of discharge. This is key in identifying when a station may be approaching loss of power. This information creates the opportunity for the logger to take steps to protect essential components.

Shunts can also be installed on the charge controllers to track solar panel output, however some loggers do not have enough open ports to support this.

Data will be logged to an independent *POWER* table. To assess power levels, solar panel function, and battery health will require both onboard and server-side calculations.

Todo

This requires changes to the program logic, and the installation and purchase of a shunt.

Cost Quantity: minimum of 1 shunt is needed per logger.

Price: a good quality sealed shunt can cost from $7 to $35

Total: **$40 - $200**

3.2.2 Combine Power Supply

Currently the aspirated fans are run on an isolated power supply. This has the benefit of isolating the logger from any power issues the fan has. However, this also prevents the logger from knowing whether or not the fan is turned on. Combining power supplies at the terminal strip has the benefit of providing *multiple solar panels and charge controllers* to the logger, so that no single failure can take down the whole system. It also has the benefit of reallocating disproportionally distributed power.

For example, here is a summary of the power supply after CENT tower is combined with CENT aspirated fan.

Station	System Daily (Ah)	Battery Bank (Ah)	< 30% DOD for 7 days	System Daily (Wh)	Solar Panel (W)
CENT Twr	12.06	624	281	144.7	200
CENT Asp	14.63	416	488	175.56	100
CEN Comb	26.69	1040	890	320.26	300

Todo

This requires time to rewire the system.

Cost 0

3.2.3 Low Voltage Disconnect

Low voltage disconnects provide protection for batteries to prevent overdischarge. This is important for long term budgeting and allows the stations to recover automatically, without the need for an operator to replace the batteries before the station comes back on line.

Currently, many installations do not have LVD's. Xantrex charge controllers can be set as either a charge controller, or a load controller. Installations with these could be repurposed to use a Sunsaver as a charge controller and a Xantrex as a load controller.

Below is a possible reconfiguration. Components that will need to be purchased are highlighted:

Station	Current Controller	Suggested Reconfiguration
UPLO Shltr	Xantrex C35	Chrg: Sunsaver 10; Load: Xantrex c35
UPLO SA	Sunsaver 10	Sunsaver 20L
CENT Shltr	Sunsaver 10	Chrg: Sunsaver 10; Load: Xantrex c35
CENT Twr	Xantrex C35	**MPPT**
CENT ASP	Sunsaver 10	**MPPT**
VAN Twr	Xantrex C35	Chrg: Sunsaver 10; Load: Xantrex c35
VARA SA	Sunsaver 10	**MPPT**
VARA Lgr	Sunsaver 10	**MPPT**

Note: MPPT charge/load controllers have ~20-25% improvement in solar power production over currently installed PWM controllers.

Todo

Reconfigure current charge/load controllers. Purchase and install new charge/load controllers.

Cost Price: $240 Sunsaver MPPT-15L

Quantity: 4 New MPPT charge/load controllers

Total: **$960**

3.2.4 Replace/Remove Unnecessary Radios

Both UPLO and CENT have 2 radios, one each at the tower and the shelter. UPLO also had a 3rd radio on the tower as a relay. In both cases, empty conduit runs between the two. By connecting the two loggers via an ethernet switch, one radio can be removed at CENT and 2 have already been removed at UPLO. This would leave only 1 network access point per station, but in the event of a network failure, the data would remain securely backed up on both the logger and the card.

VARA, CENT, and VAN have high draw Tranzeo radios. These can be replaced with lower draw Nano-locos. This would significantly reduce the power demands at these stations.

Station	System Daily Ah	Network Daily Ah	Netwrok %	Change in Ah	New Daily Ah	% Reduction
UPLO Twr	10.35	9.0	79	-3.98	6.37	38
UPLO Shlt	5.76	5.0	87	-3.98	1.77	69
CENT Shlt	2.0	1.3	64	-0.73	1.75	13
CENT Twr	9.43	8.0	86	-3.05	6.42	32
VARA	8.65	8	93	-3.05	5.64	35
VAN Twr	9.8	8.0	82	-3.05	6.75	45

Todo

VAN,VARA, CENT - Replace Tranzeo radios with Nano-Loco radios

CENT, UPLO (completed) - Remove shelter radios and run ethernet cable from shelter to tower

Cost 2 Nano-locos must be purchased.

3.2.5 Control Network and Fan Operation

Network infrastructure and aspirated fans draw more current than any other component because they are running constantly. It is important to be able to shut off their power to save critical components during low power operations. Radios and fans serve different purposes that require different control logic, but both can be controlled with the same mechanism. By powering both components from the 12 v switch on the logger (SW12V), they can be switched off to save logger function. A manual override is also needed, to cut all power regardless of program logic.

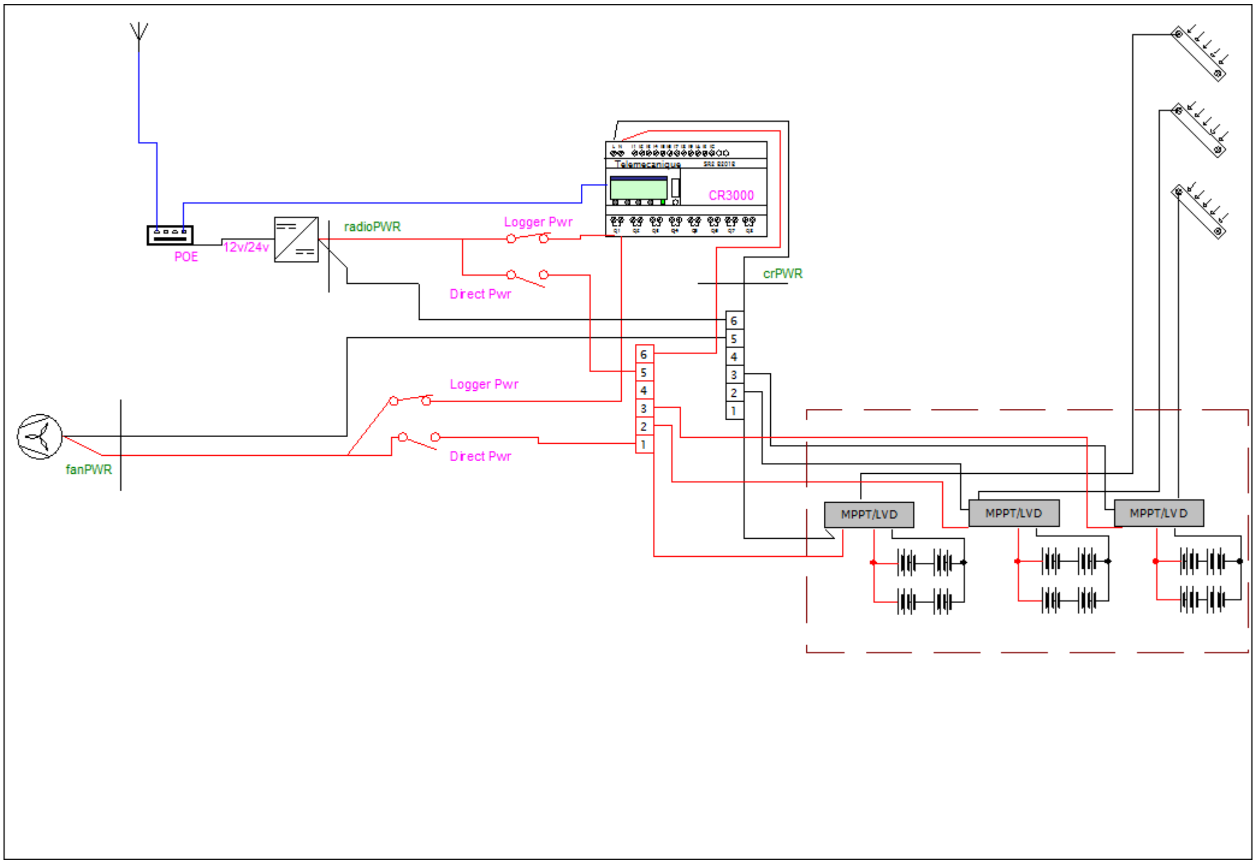
Note: The NL116 should be turned off with the loggers. The card and ethernet port combined draw 1.03 Ah per day.

Example Code

```
'Example from RV50 mannual
'SW12 Voltage Control
'Turn ON SW12 between 0900 hours and 1700 hours
'for 20 minutes every 60 minutes
If BattV >12.5
If TimeIsBetween(540,1020,1440,Min) And TimeIsBetween(0,15,60,Min) Then
SW12State=True
Else
SW12State=False
```

```
EndIf
'Always turn OFF SW12 if battery drops below 11.5 volts
If BattV<11.5 Then SW12State=False
'Set SW12-1 to the state of 'SW12State' variable
SW12(1,SW12State,0)
```

Example Wiring Configuration



Todo

- **Develop control logic**
  - Minimal power mode where the radio and fan are shut down
  - Different radio schedules for different power levels
- Rewire radios and fan to 12v switch
- Purchase and install manual switches

Cost Quality switches cost $15 - $50.

Quantity 14 (4 switches x [VAN, UPLOTwr, CENTTwr] + 2 at VARA).

Minimum **$210**

Radio Controls

Unlike the aspirated fan, the network infrastructure does not need to be on all of the time. The network can be cycled on and off to transmit for discrete periods of time. During periods of low power the radio could turn on for one hour every afternoon. During good weather the radio could turn on for 5 minutes each hour. **Using the radio changes discussed** above, here are the **additional effects** of reducing radio transmission time. Redux % represents the reduction in Ah as $\frac{NewRadioDailyAh - ReducedTransmissionTimeAh}{2015Ah}$

Station	New Radio Daily Ah	Daily Ah 24 x 5 min	Daily Ah 1 x 40 min	Daily Ah 4 x 20 min	Redux % (2015 Ah)
UPLO Twr	6.37	1.77	1.49	1.63	44 - 47
UPLO Shlt	1.77	NL116 Power must be	timed with Twr		
CENT Twr	6.42	1.82	1.54	1.68	49 - 52
CENT Shlt	1.75	NL116 Power must be	timed with Twr		
VARA	5.64	1.29	0.84	1.07	49 - 53
VAN Twr	6.75	2.15	1.87	2.01	41 - 43

Todo

Change logger programs to shut down NL116 and radios and provide power at limited intervals

Cost 0

3.2.6 Separate Housing For Charge Controllers

Currently charge controllers are mounted horizontally on top of the batteries in the battery boxes. This can potentially damage or destroy the charge controllers due to overheating, and the corrosive gases released as the batteries charge. As described by the Morningstar Corporation:

Warning: Equipment Damage or Risk of Explosion
Never install the SunSaver in an enclosure with vented/flooded batteries. Battery fumes are flammable and will corrode and destroy the Sunsaver circuits.
Equipment Damage
When installing the Sunsaver in an enclosure, ensure sufficient ventilation. Installation in a sealed enclosure will lead to over-heating and a decreased product lifetime.
Mounting the controller on a horizontal surface does not provide optimal airflow and could lead to overheating.
Safety Precautions
Install the Sunsaver in a location that prevents casual contact. The SunSaver heatsink can become very hot during operation

Because of the importance of convective cooling it is important that they be placed in vented enclosures. However, due to the high amount of mist and fog at the stations, an outer shelter is also needed, possibly sealed like reference stands.

Todo

- Construct outer shelters

- Mount shelters to tower
- Rewire solar panels and batteries

Cost 4 vented enclosures will cost a minimum of $200

3.3 Projected Power Use

The summary below is the projected power supply and demand after the upgrades discussed above are implemented. Aspirated fans are now included in estimates for all towers. Numbers are estimates using the methods described previously and under powered components are highlighted.

Station	System Daily (Ah)	Battery Bank (Ah)	<30% DOD for 7 days	System Daily (Wh)	Solar Panel (W)	Winter Need (W)
CENT Twr	16.45	1040	548.33	197.40	300	286.09
CENT Shl	1.75	416	58.33	21	**50.2**	**72.75**
UPLO Twr	16.40	1248	546.67	196.80	360	285.22
UPLO Shl	1.77	416	59.00	21.24	240	30.78
VAN Twr	16.78	1456	559.33	201.36	**262.6**	**291.83**
VARA	1.29	208	43.00	15.48	131	22.43

This projection indicates that VAN Tower and CENT shelter will be underpowered during the winter. In both cases, if the smallest solar panel were replaced with 1- 140W panel, the station should generate close to the daily power demand during winter.

The estimates used here are rough estimates, that do not include such details as: voltage drop, heat loss, temperature corrected battery Ah, temperature corrected solar output, and light intensity corrected solar output. The estimates provided are likely inaccurate, but they are precisely calculated. Their primary function is to allow improvements to be prioritized.

CHAPTER 4

Indices and tables

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