POWERING A SENQUIP DEVICE WITH SOLAR

1. Introduction

Senquip ORB and QUAD devices can be powered with DC from 10V to 75V, using AA batteries (Senquip ORB only), or using solar. In most solar systems an external regulator and battery are not needed, with the internal LiPo backup battery powering the Senquip device and attached sensors during the night. External sensors, and device settings impact solar system performance and will be discussed along with the choice of solar panel.

This application note focusses on solar; for further information on general low power applications, see application note APN0004.

Figure 1 - Battery Powered Senquip ORB Monitoring Water Level

2. Impact of Device Operation on Power

Senquip devices can be configured to take periodic measurements, process, transmit, and then to return to sleep. A simplified flowchart of Senquip device operation is shown in Figure 2. The aim of any low power application is to minimise the time that the device spends taking measurements, processing, and especially transmitting, and to maximise the time the device remains in sleep.

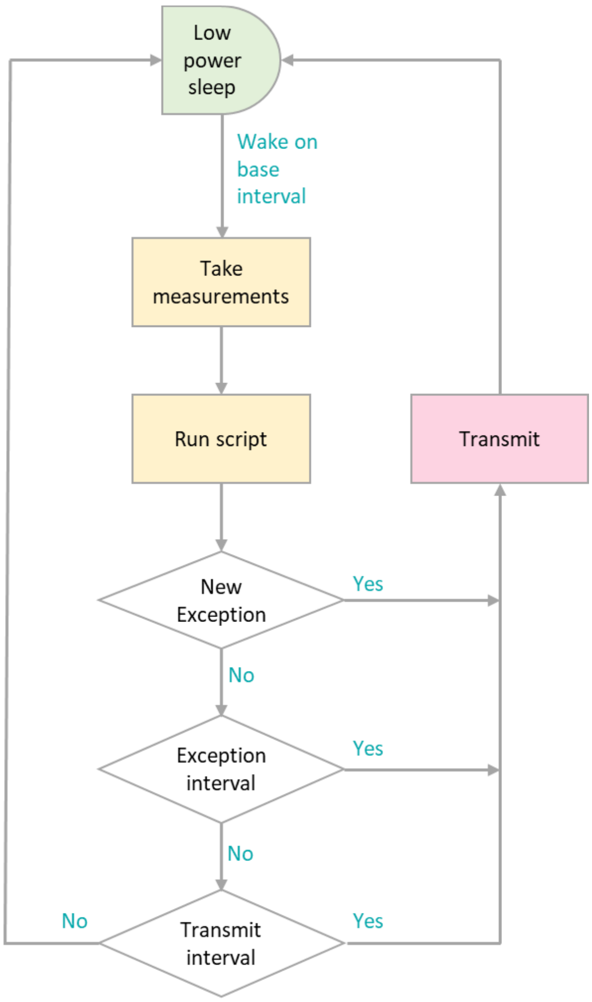

Figure 2 - Simplified Device Operation

Sleep mode: The Senquip device turns off all peripherals and enters a very low power mode. The device is not contactable at this time and if the cover is opened, the lights will remain off. The only way to exit sleep mode is by pressing the setup or reset button or with one of the peripherals that can wake the ORB from sleep.

Measurement mode: When the device wakes from sleep, it starts a measurement cycle. Required peripherals are turned on and the device starts processing measurement data. Power consumption increases in accordance with which peripherals are turned on, what is attached to the peripherals and for how long the peripherals are kept on.

Transmit mode: Once all measurements are complete, the device will transmit the measured data to the Senquip Portal or other endpoint. Transmission is the most energy intense operation and as such, has the greatest impact on battery life. The power consumed during a Wi-Fi and LTE transmission are different and will also depend on factors such as distance from tower and weather conditions.

Mode	Current consumption	Power consumption
Sleep	65uA	227uW
Measurement	50mA	175mW
Transmit (WiFi)	100mA	350mW
Transmit (LTE)	150mA	525mW

Table 1 - ORB-C1-G Typical Power Consumption

As shown in **Error! Reference source not found.**, the measurement and transmit power consumption of the ORB is more than 1000 times that of sleep mode. Keeping the ORB in sleep mode for as long as possible will therefore has a massive impact on how long the device will be able to operate off its internal LiPo in the absence of sunlight.

Figure 3 shows a Senquip device that is taking measurements from 2 x 4-20mA sensors every 10 minutes. As can be seen from the chart below, in perfect conditions, the system voltage, which is derived from the internal LiPo, barely drops overnight. Measurement intervals shorter than 10 minutes are typically not suitable for solar applications as the time spent awake and transmitting becomes too high a percentage of time.

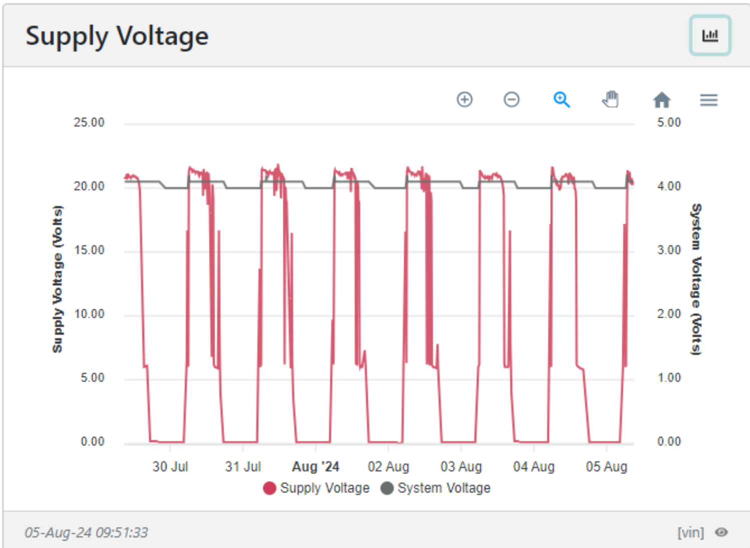

Figure 3 - Perfect Sunlight for a Week

***Insight 1**: Keep the Base Interval as long as possible – ideally longer than 10 minutes.*

The following settings were applied to the device shown in Figure 3:

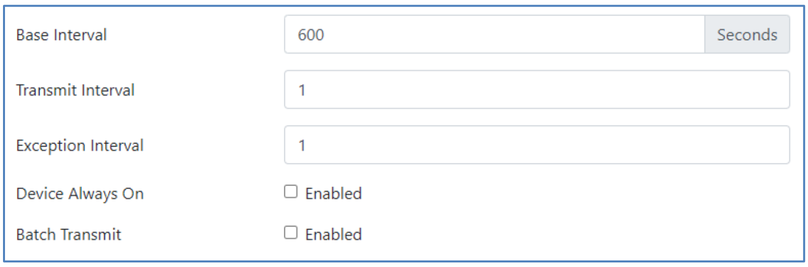

Figure 4 - 10 Minute Base Interval in Solar System

The transmit interval of 10 minutes is suitable for a solar installation. Further optimisation could however have been made by limiting the number of transits. By changing the *Transmit Interval* to 6 and enabling *Batch Transmit*, the number of transmits and the time that the device spends transmitting will have been reduced by a factor of 6. In the example below, the same number of data points will be received, and if an exception is registered, the transmit interval will immediately return to every 10 minutes.

To further reduce power consumption, disable *Batch Transmit* which will configure the device to transmit only every 6th cycle. This adjustment will decrease the volume of transmitted data by a factor of 6. Again, when an exception is detected, the transmit rate will return to normal. Never enable Device *Always On* operation or enable the *Web Server* in a solar application.

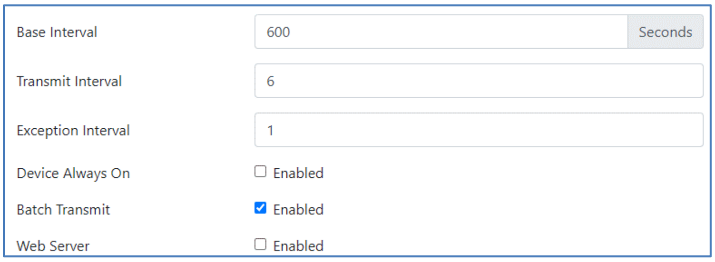

Figure 5 - Optimised Transmit Time in Solar System

***Insight 2:** Reduce the Transmit Interval where possible.*

In some applications, the measurement interval can be reduced at night, or when solar activity is low. To achieve this, enable *Hibernate on Power Loss* and set the *Hibernate Interval* to a suitable measurement interval. In the example in Figure 6, the device will enter hibernate mode after 5 *Base Intervals* with no solar. It will then start reporting at 20 minute (1200 sec) intervals instead of 10 minute intervals.

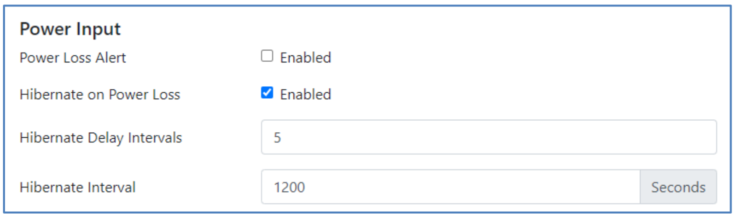

Figure 6 - Slower Measurement Intervals in Low Sunlight Conditions

***Insight 3:** Use Hibernate to reduce measurement intervals in low light conditions.*

Adding additional user endpoints will increase power consumption as a transmission time is increased. I additional endpoints are required, use MQTT rather than HTTP to reduce connection time.

3. Choice of Sensors

Many solar powered applications are monitoring water level using 4-20mA level transmitters like the one shown in Figure 7. These sensors typically run of 12V. Senquip devices can power external sensors in the absence of a supply voltage by boosting the internal backup battery to a level suitable for the sensor. If one assumed that a sensor was powered with 12V and is drawing 20mA, then it is using 240mW of power. To provide 240mW from the internal battery, which when fully charged is approximately 4V, requires 60mA to be drawn from the battery. This will drain the internal 1800mAh battery quickly. Senquip has therefore provided a mechanism to allow external sensors to be powered, measured, and turned off.

Figure 7 - Typical Tank Level Sensor

In the Senquip ORB setup shown in Figure 8, a 4-20mA level sensor is set to be measured on every base interval. On each interval, the sensor will be powered for 1 second before being measured. This allows time for the sensor to boot, and for the output to stabilise.

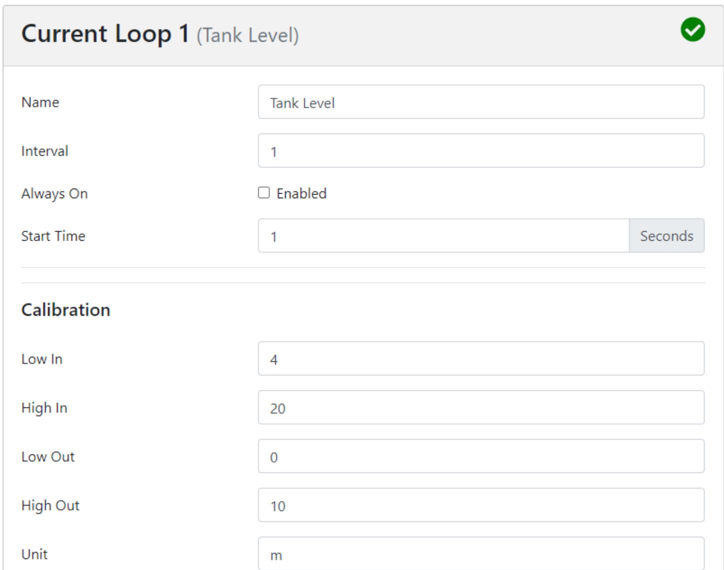

Figure 8 - Typical 4-20mA Device Setup

In this example, with a base interval of 2 hours, and operating on Wi-Fi, the system ran from 26th November 2023 till 18 May 2024 (173 days) with no external power at all, running only off the internal backup battery. Figure 9 shows that the internal battery started at 4.14V, and that the device went into shutdown 173 days later when the battery reached 3.6V.

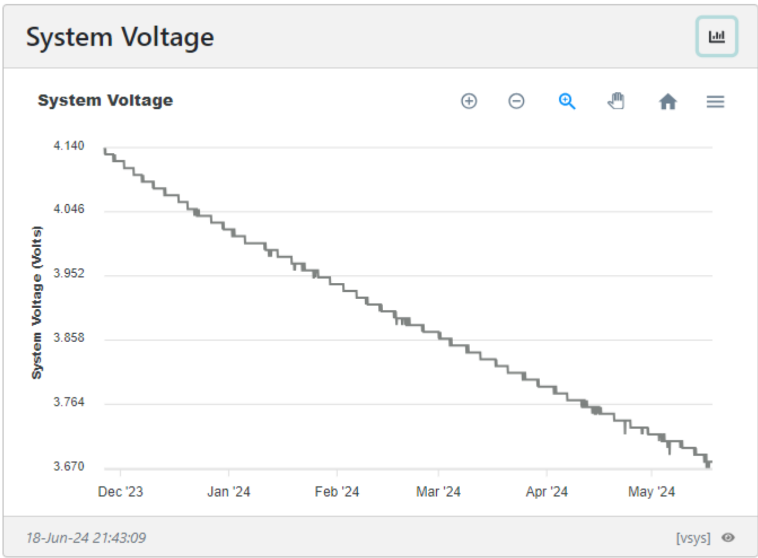

Figure 9 - Water Level Sensor Running 173 Days Without External Power

Boot time can vary drastically depending on the sensor chosen. For instance, the VEGAPULS C 21 Two-wire 4 … 20 mA radar sensor specifies a run-up time of 15 seconds (Figure 10). In addition, 0-999 seconds of damping can be applied. Many of these radar sensors are used successfully with Senquip devices in solar applications, consideration does however have to be given to the measurement interval because with a start time of 15 seconds vs 1 second for the pressure based sensor, the radar sensor will use 15 times more energy.

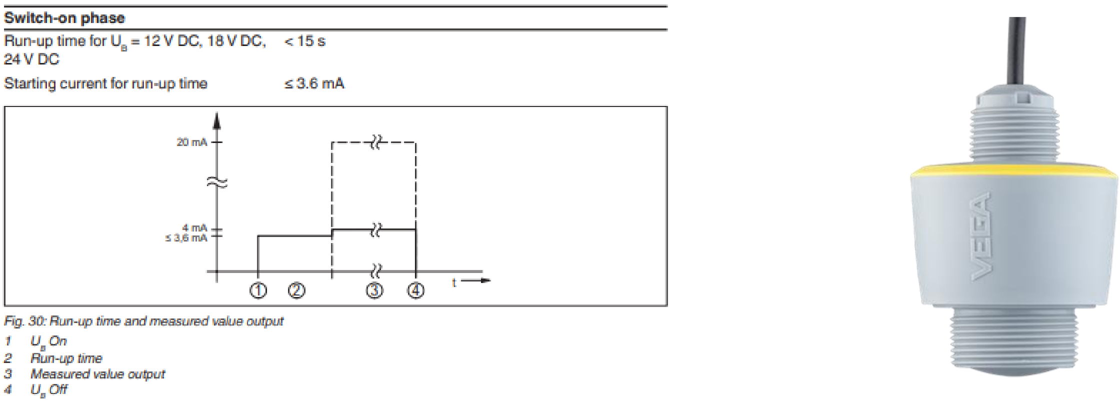

Figure 10 - VEGAPLUS C21 Radar Level Sensor Boot Time

When designing a solar system, the sensor plays a critical role in determining the power consumed from the internal battery. So far, we have discussed 4-20mA sensors, however it may be more suitable to use voltage output sensors, or Modbus sensors that draw less than 4mA.

> ***Insight 4:*** *Use low power sensors and consider power draw and total measurement time.*

3.1. GPS, Bluetooth, and Other Internal Sensors

Integrated GPS (GNSS) and Bluetooth peripherals will add greatly to power consumed if enabled.

The use of GPS will add approximately 30mA to current drawn. More damaging is that GPS will hold the Senquip device on until it acquires satellites. The default time to wait to allow for satellite acquisition is 180 seconds.

For applications that require GPS, it is recommended that the GPS interval be set so that it is sampled irregularly. In most solar applications, the site location will be fixed and so an update once a day should suffice. If the aim of GPS is to geolocate the device at installation, then set the GPS interval as a very high number (once a month). The GPS will be sampled the first time the device is powered, or after a reset and so a geolocation will be reported.

For applications that need to sample Bluetooth sensors, the scan time needs to be managed carefully. During sampling, the Senquip device will be held on, and the Bluetooth peripheral will be in receive mode. If a scan time of 5 seconds is set, all Bluetooth sensors will need to be transmitting at a rate faster than 5 seconds. The trade-off is that a lower scan time on the Senquip device will mean a faster transmit rate on the sensor.

The internal light sensor, temperature sensor, and accelerometer will add almost no power consumption and can be useful for detecting tamper, hot batteries, and an installation is no longer upright.

Specifying a Solar Panel

Solar panel specification can be misleading.

The voltage of a solar panel is often specified as the open circuit voltage (V_{oc}). This is the maximum voltage that the panel can produce with no load on it. Current is often specified as the short circuit current (I_{sc}). This is the measured current when the panel leads are shorted together. Open circuit voltage is useful to ensure that the panel voltage will not exceed the input specification of the Senquip device. A solar panel with an open circuit voltage not exceeding 75V is suitable for use with a Senquip device.

In both the open circuit voltage and short circuit current scenarios, the panel is producing no power because either the voltage or current are zero (volts x amps = watts). Somewhere between these conditions, typically at midday, the solar panel will produce maximum power output (MPP), where the combination of volts and amps results in the highest possible power. This is typically the power rating specified for a panel.

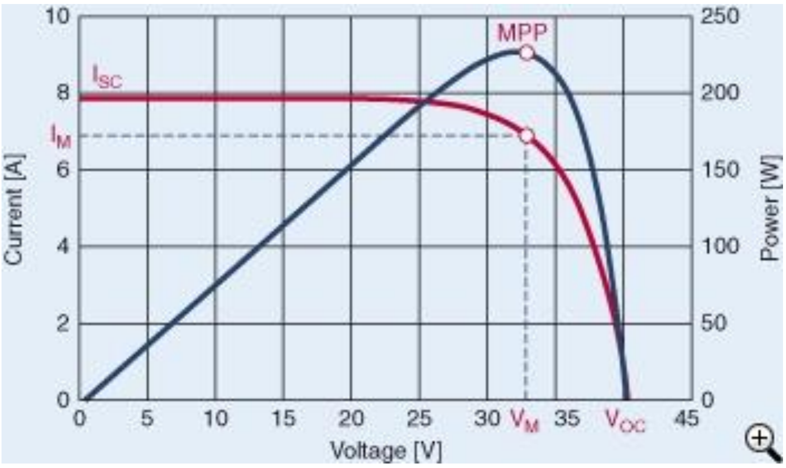

Figure 11 - Power Curves for a Typical Solar Panel

3.2. Connecting the Solar Panel

A solar panel can be connected directly to the Senquip device. A solar regulator is not required.

Where a 4-20mA or other sensor needs to be powered by the Senquip device, on an ORB, the current source pins can be used, and on a QUAD, any of the IO can be used. On the ORB, a 12V supply will be enabled on the source pins during a measurement. On the QUAD, the supplied voltage can be specified between 5V and 25V.

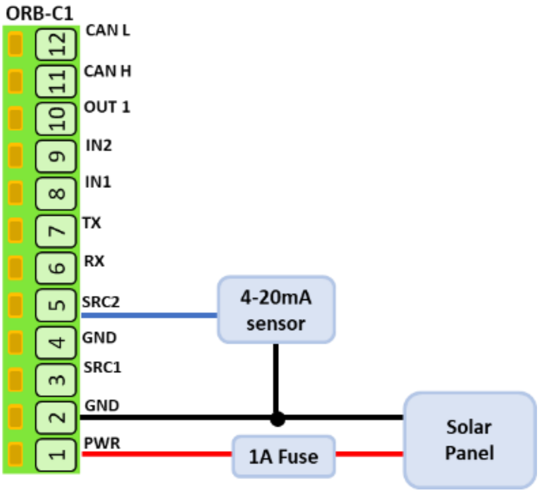

Figure 12 - Typical Solar Panel Wiring

AA batteries are not required in a solar install. At least, they may be able to backup the system during a spell of low sunlight days. At worst, they are never used and over time corrode and damage the device. It is better to design the system to account for rainy days than to rely of AA batteries. If you do decide to use AA batteries, Energiser Lithium are recommended as they have high energy density with the ability to provide high pulse currents, and they are the least likely to corrode.

Figure 13 - Energiser Lithium Batteries are Recommended if Required

3.3. Calculating the Required Wattage

To calculate the solar panel required, we need to understand how much energy the Senquip device and attached sensors are using.

We will use the [ORB Battery Calculator] to estate daily energy requirements and will use an example where measurements are taken every 10 minutes from 2 x 4-20mA sensors with a boot time of 5 seconds.

ORB Current Calculator Rev 1.2					
					Notes
Base Interval	seconds	600	Measurements per day	144	
			Ave mAh per measure	0.03	
			mAh per day	4.00	Overhead
Sleep	seconds	593	mAh per day	0.00	Sleep current
Transmit Interval	units	1	Transmits per day	144	
Network		GSM	Ave mAh per Transmit	4.60	good -60dBm < WiFi < -70dBm poor
Reception		Poor	mAh per day	662.40	good -70dBm < GSM < -80dBm poor
GPS Interval	units	0	GPS acquisitions per day	0	
			Ave mAh per acquisition	2.50	Average GPS coverage
			mAh per day	0.00	GPS
Current Loop 1 Interval	units	1	Current Loop 1 per day	144	
Start Time	seconds	5			
Current	mA	20	Ave mAh per measurement	0.10	Up to 100mA at 12V
			mAh per day	14.55	Current 1
Current Loop 2 Interval	units	1	Current Loop 2 per day	144	
Start Time	seconds	5			
Current	mA	20	Ave mAh per measurement	0.10	Up to 100mA at 12V
			mAh per day	14.55	Current 2
			Total mAh per Day	695.49	
			Total Wh per Day	2.50	
Batteries		none	mAh	0	
			Voltage	3.6	
LiPo		Charged	mAh	1800	
			Voltage	3.7	
			Total mAh Available	1715	
Expected ORB Life	**days**	2			
	years	0.0			

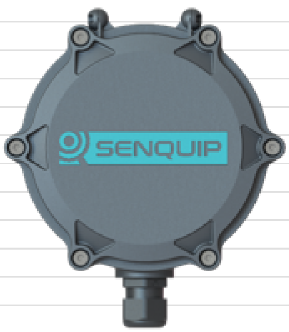

Figure 14 - Calculating Power Used by a Senquip ORB and 2 x 4-20mA Sensors

From the calculator, we see that our system uses approximately 2.5Wh per day. A simple formula allows us to calculate the required solar panel size. In the formula, the consumption is 2.5Wh.

PV Size [W] = Margin x (Consumption [Wh]) / (Light Exposure [h])

The margin accounts for parameters like charging efficiency and the number of days you would like to run without sun. Light exposure is the number of hours in a day that the panel is exposed to sufficient light to charge the internal battery.

Taking Sydney Australia as an example of a high sunshine area, the following sunlight exposure data is provided by the Bureau of Meteorology. From the data, we see that 6 hours is the lowest for July. Keep in mind that if the panel is mounted facing South, this value will be lower. We will assume a well-placed panel and will use 6 hours for the light exposure.

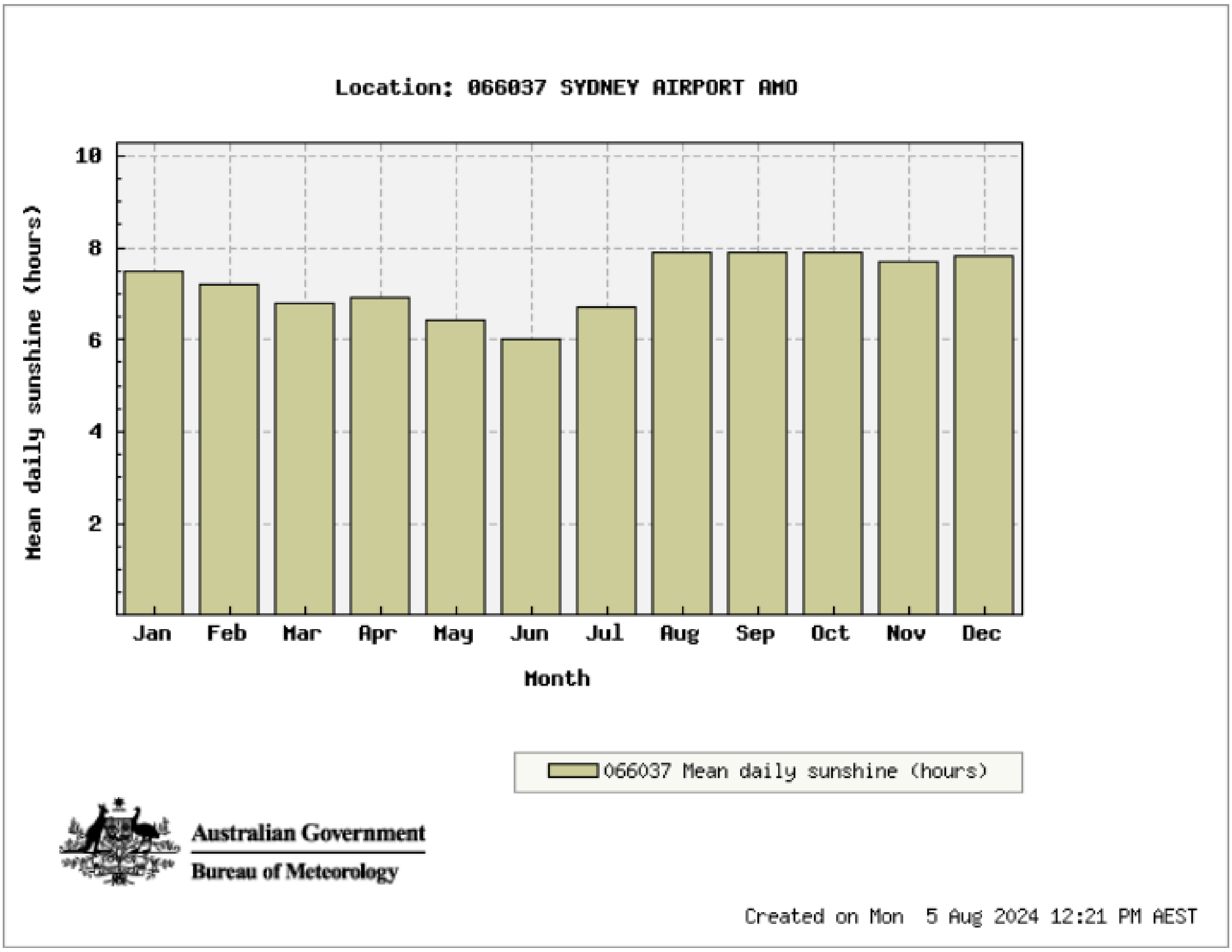

Figure 15 - Average Sunlight Hours for Sydney, Australia

The margin incorporates all the other factors like the efficiency of the panel (vs rating), dust on the panel, efficiency of a charging cycle, and how long we would like to be able to go without sun.

If we assume that the panel is 50% efficient, and the charging cycle is 50% efficient, and that we want to be able to go without sun for a week and be able to recharge in a day, the margin will be 2x2x7 = 28.

Applying these numbers, our panel needs to be 28 x 2.5 / 6 = 11.7W. As a rule of thumb, in most simple solar cases, we recommend a 20W solar panel similar to the one shown in Figure 16.

Figure 16 - 20W Solar Panel Kit from Macquarrie Corporation

Insight 5: *Be conservative in your choice of panel.*

4. System Placement

Placement of solar panels and the Senquip device can impact the available charge, the ability to charge the internal battery, and power consumption during transmit.

4.1. Solar Panel Placement

For applications in the Northern hemisphere, panels are typically South facing to capture the most sunlight. In the Southern hemisphere, panels typically face North. The ideal angle for a solar panel installation is the latitude of the install location.

Even partial shading of your solar panel can reduce the efficiency of your entire panel by up to 80%.

If your panels cannot face North or South, and the ideal tilt angle is not achievable, or there will be shading on the panels, the margin should be increased in the panel size formula.

Figure 17 - Solar Panel with Partial Shade

4.2. Device Placement

The quality of cellular or Wi-Fi signal has an impact on the energy used to transmit data. For instance, in our example where we used 2.5Wh per day, if the cellular signal was optimal, we could have reduced that to approximately 0.74Wh. By monitoring RSSI in the device diagnostics, positioning for the best signal can be achieved. A falling RSSI over time can be a good indicator of antenna damage.

Charging of the internal LiPo battery will be terminated at high temperatures. In very high temperature environments, shade should be provided for the device.

Insight 6: *Consider panel and device placement.*

5. In Field Testing

In any application, Senquip suggests that a trial setup be tested in-field. During trials, the supply voltage should be monitored, and should not go below 3.7V in a worst case situation. Figure 18 shows the voltage generated by a solar panel during a rainy period. As can be seen in the diagram, the system voltage drops to 3.7.

The load on the internal battery is too high and so either the *Base Interval* must be increased, or the number of transmits reduced by increasing that *Transmit Interval* or using hibernate functionality.

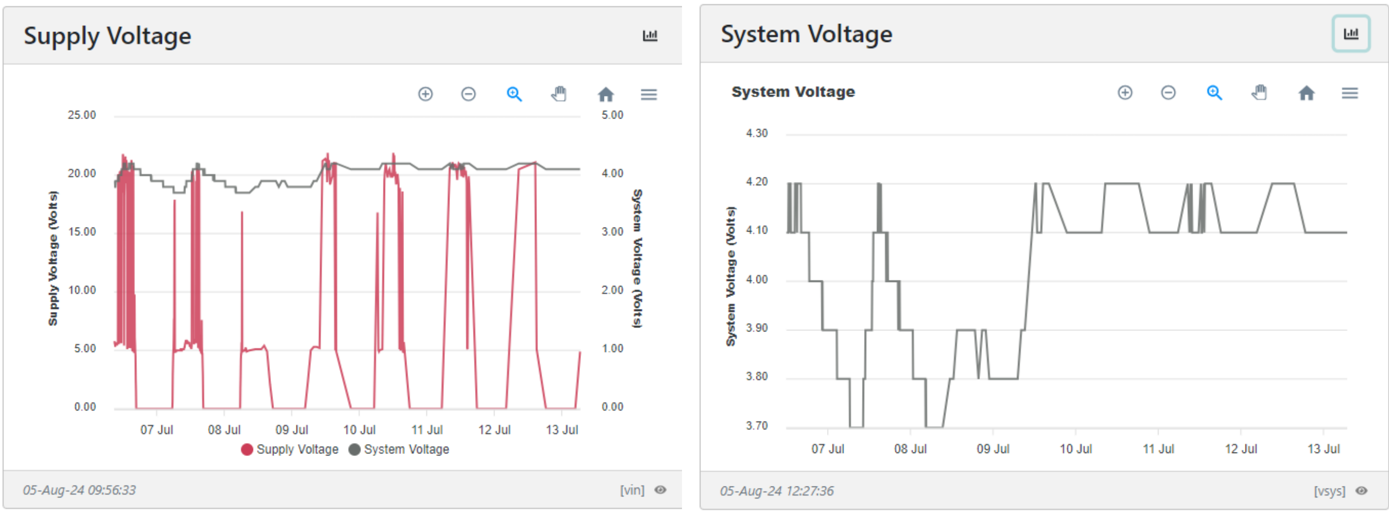

Figure 18 - Solar Power Generation During a Rainy Period

Continued monitoring of the system voltage for deployed systems will provide a reliable metric for solar system performance. For instance, an alert on the system voltage could provide advanced notice that a panel need cleaning, or that vegetation has grown up around a panel. In a recent install, a fence was constructed post the solar install. A fence post shaded part of the solar panel for much of the day, resulting in an alert being generated. The solar panel was lifted, and the system is operating correctly again.

Insight 7: *Continuous system voltage monitoring and alerts will predict a failing solar system.*

6. Conclusions

Solar systems using a Senquip ORB or QUAD, and external sensors typically do not need a solar regulator or external battery. The internal backup battery can power external sensors in a correctly configured system for days or months.

The *Base Interval, Transmit Interval,* and Hibernate functionality allow the user to tailor the Senquip device for most solar applications. Choosing external sensors that are low power and boot quickly can help extend the life of the system in the absence of sunlight. Peripherals like the GPS and Bluetooth use a lot of energy and should be used sparingly.

Through consideration of your location, the energy used by the system, and efficiency factors, the size of a suitable solar panel can be determined. The cost of solar panels is low, the cost of servicing a remote site it high. Be conservative with the solar panel size estimation.

The location and mounting of the solar panel have an impact on energy it can produce. Solar panels should be mounted to capture maximum sun without partial shading. The Senquip device should have maximum signal strength and should be shaded in extreme environments.

Continuous monitoring, particularly of the system voltage, allows for preventative maintenance.

Figure 19 - Solar Powered Tide Monitor

7. Appendix I – Typical Device Settings

The settings below are suitable for a Senquip device powered by solar that has two connected 4-20mA sensors.

System Specification:

Reporting Interval	10 minutes
Solar panel	20W, 24V open circuit voltage
Connected Sensors	2 x 4-20mA with 5 sec measurement time
GPS	1 reading per day

Recommended Settings:

General Settings	**Value**	**Notes**
Base Interval	600	
Transmit Interval	1	
Exception Interval	1	
Device Always On	Not Enabled	
Batch Transmit	Not Enabled	Not applicable as transmit interval is 1
Web Server	Not Enabled	
Power Loss Alert	Not Enabled	We do not want an alert every night
Hibernate on Power Loss	Not Enabled	We could enable this to reduce reporting when there is no sun
Hibernate Delay Intervals	Not Enabled	
Hibernate Interval	21600	Default. Change this if hibernate is enabled
Count Hours	Not Enabled	Could be interesting to count sunlight hours
AA Battery Low Alert	Not Enabled	We have opted to not use AA batteries
Threshold	4.8	Not applicable as we are not using AA batteries
Tamper Alert	Enabled	Useful to know if the enclosure has been opened
Internal Settings	**Value**	**Notes**
Tamper Alert	Enabled	Useful to detect unauthorised lid removal
Internal Temperature Interval	1	Useful to monitor battery temperature
Accelerometer Interval	1	Useful to monitor solar panel angle
GPS Interval	144	1 day at 10 minutes intervals
External Settings	**Value**	**Notes**
Current Loop 1 Interval	1	
Current Loop 1 Mode	Current	
Current Loop 1 Always On	Not Enabled	
Current Loop 1 Start Time	5	5 seconds before sensor is sampled to allow sensor boot time
Current Loop 2 Interval	1	
Current Loop 2 Mode	Current	
Current Loop 2 Always On	Not Enabled	
Current Loop 2 Start Time	5	5 seconds before sensor is sampled to allow sensor boot time
Endpoint Settings	**Value**	**Notes**
Offline Buffer	Not Enabled	Sending buffered data will hold the transmitter on for longer
UDP	Not Enabled	Additional endpoints will increase power consumption
HTTP	Not Enabled	Additional endpoints will increase power consumption
MQTT	Not Enabled	Additional endpoints will increase power consumption