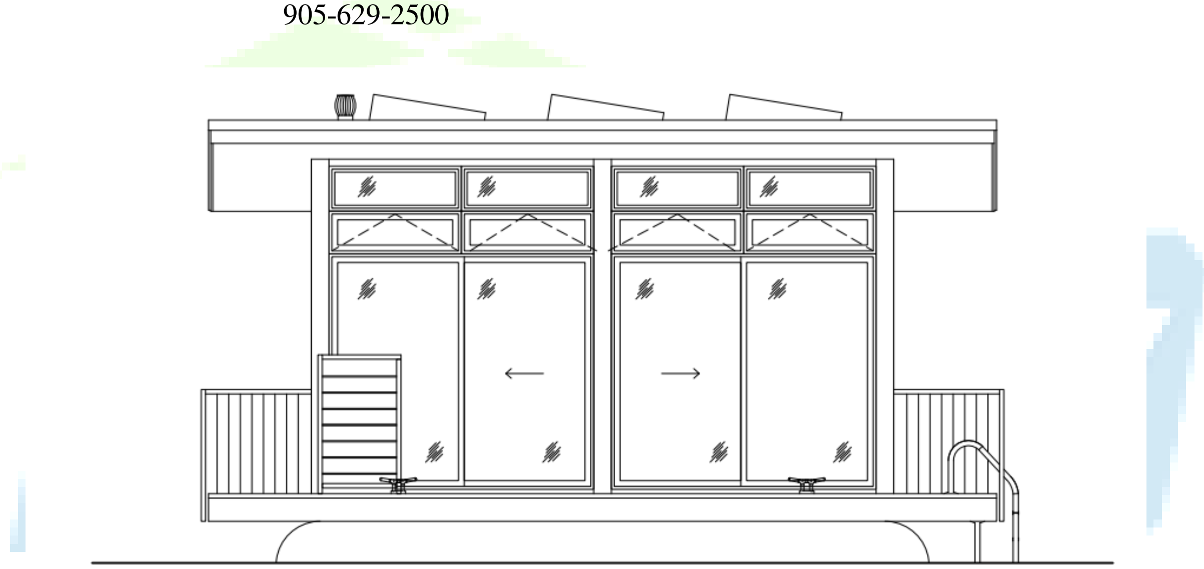
Parks Canada Floating Accommodations Engineering Sizing Report

Parks Canada

Prepared For: John B. Stark
Stark Architects INC
stark@starland.ca
905-629-2500



Prepared By: Jeremy Brooks
Electrical Engineering Co-op
HES@hespv.ca

Ed Knaggs, P.Eng
Electrical Engineer
eknaggs@hespv.ca

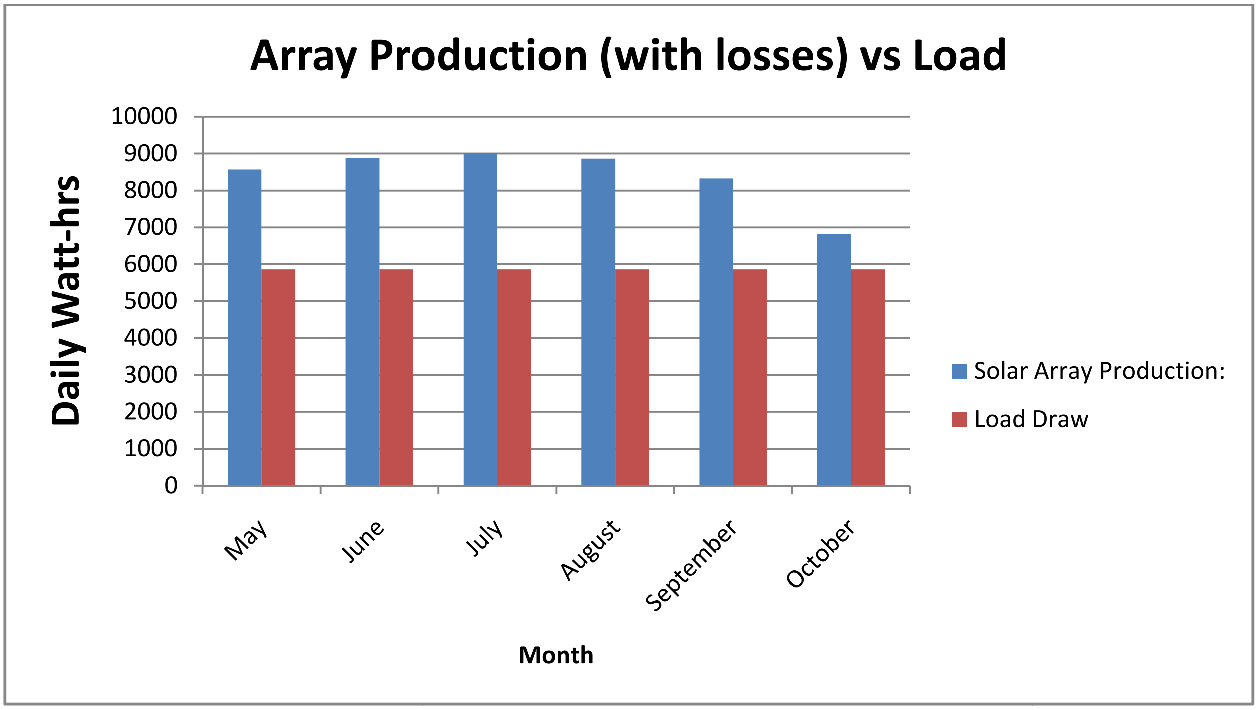
H.E.S. PV
320 Mary St
Victoria, BC V9A 3V9

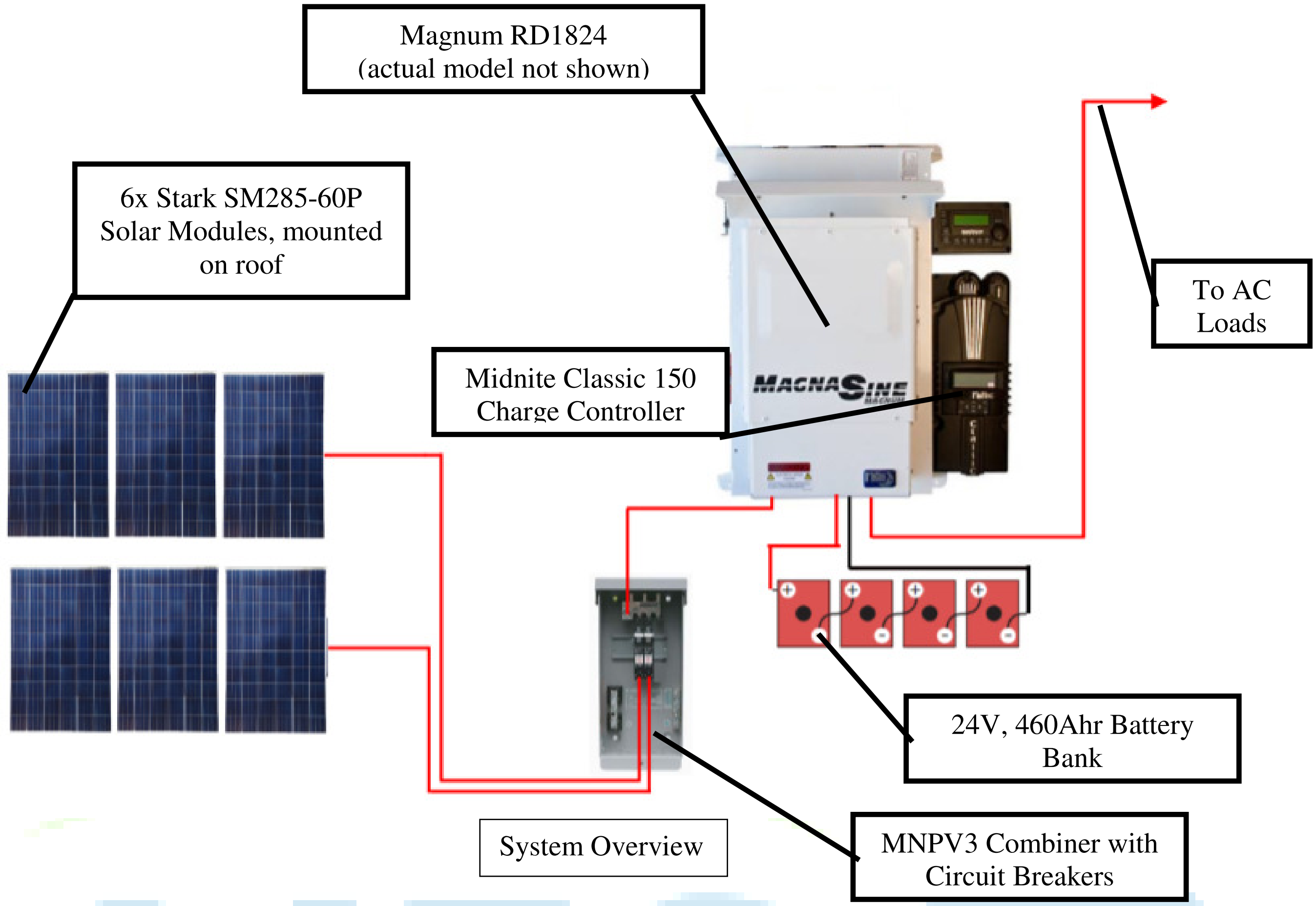
Jan 2017 Doc: 105044 (Rev B)

Summary

Based on the loads associated with each site, and the proposed locations, HES recommends that the following equipment be used on the repeater sites.

Solar Array Size	1,710 W
Solar Module	6x Stark 285W Solar Module
Charge Controller	Midnite Classic 150V Charge Controller
Amp Hour Capacity of Battery Bank	460 Ahr @ 24Vdc
Battery	4x Rolls S6-460 AGM
Inverter	Magnum RD1824 – Modified Sine Wave

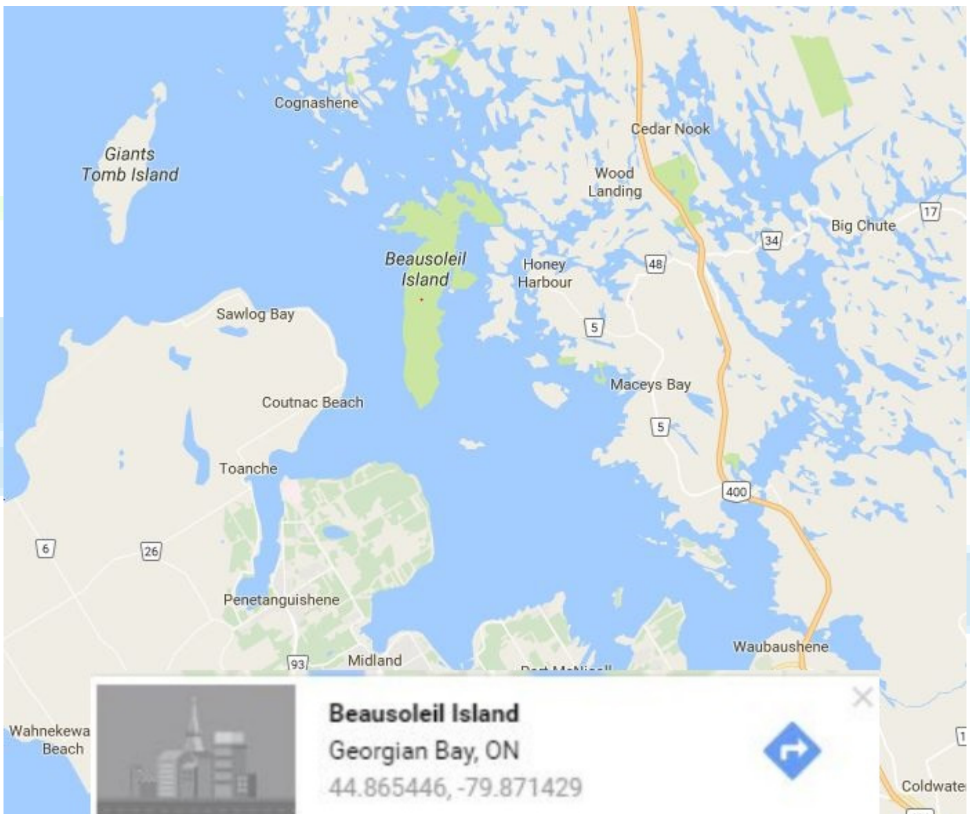




System Overview

Location Information

The Parks Canada floating accommodations system is scheduled for deployment in the Georgian Bay National Park, however it is Parks Canada's intention to deploy this model in other National Parks if successful. The first deployment location, as listed on the architectural drawings is Beausoleil Island near Midland Ontario. For modeling purposes this location was determined to be at Lat 44.86, Long -79.87. At the latitude and longitude determined, the site climate data was retrieved using the NASA GIS and meteorological dataset. The climate data that NASA uses is averaged over a square kilometer and the dataset that was retrieved was for an average elevation of 258m.



Site Location

DATA

Parks Canada has requested HES PV Limited conduct an analysis of the required energy to run equipment using a battery based solar system on a floating accommodation that is intended to be used by campers during the camping season.

Electrical Loads:

HES PV was provided with the electrical load requirements for the off grid floating cabin system. Each of these cabins will contain a compostable toilet with a heater and fans, a propane gas fireplace, 4 LED recessed lighting and a small bar fridge. This system will also contain 120VAC outlets for charging of campers' laptop PCs, cellphones, tablets and battery powered lighting. Campers are to be instructed on energy management techniques to conserve battery power and to not run any heavier equipment such as hair dryers, toasters, coffee machines etc. The load summary for this equipment is detailed below:

Table 1: Load List

Equipment	Model #	Power (W)	Est. Hours of Use	Daily Load Draw (Whr)
Bar Fridge	Danby DAR026AWDD	24		693.1 *
Composting Toilet- with Heating	Envirolet MS-10	540	6	3240
Composting Toilet-Fans Only	Envirolet MS-10	40	18	720
Recessed Lighting (4x LED Lights)	Edge Sun3C	30	12	360
Laptop	Average consumer grade	40	6	240
Tablet PC -Ipad	Average consumer grade	15	6	90
Cellphone Charging	Average consumer grade	10	6	60
Camping Light	Average consumer grade	40	2	80
Inverter- Search Mode	Magnum RD1824	5	0	0
Inverter-No Load	Magnum RD1824	12	24	288
Charge Controller- Standby	Midnite Classic 150	4	**24**	96
	Total Power:	858.4 W	**Total Draw:**	5867.1 Whr

*DOE EnergyStar Criteria. www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls. Note that "standard" values are the maximum allowed by National Appliance Energy Conservation Act.

Warning: This system was designed for the loads provided above. Any variation in the load could reduce system reliability. If the loads are changed are increased the system may need to be expanded.

The largest load for this system will be the composting toilet, due to the heavy electrical costs of heating the compost material. This unit is to be fitted with a timer circuit which will only allow the heating element to be on for a maximum of 6 hours a day during peak use. While the heating is not in use the toilet will be in "fan only" mode and will draw a smaller electrical load (~40W). The design and installation of this time circuitry is outside of the scope of work that HES PV was asked to perform.

Due to the constrained energy storage capabilities of this system it may be worthwhile for Parks Canada to investigate propane gas powered composting toilets to reduce the electrical power draw.

Originally, the fireplace chosen for this system was the Napoleon GT8P "Torch" propane fireplace, however it was found that the electrical load for the control and ignition circuitry for this fireplace was too high. It is the understanding of HES PVthat this fireplace is to be replaced with a Napoleon fireplace with a "millivolt" ignitor which does not need to be hardwired and will not require any electrical load.

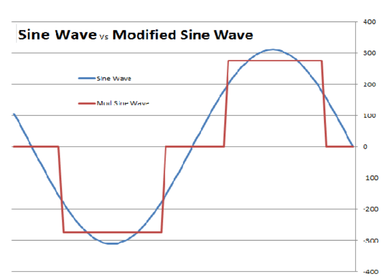
The daily average load draw for the refrigerator is relatively low compared to the other loads, however energy management techniques may be employed to further reduce the demand. Campers should be informed to reduce the time the refrigerator door is open. As well, the cabin operator may request that the campers keep the temperature setting of the refrigerator kept at a set value. The interior and exterior LED lighting may also be put on separate circuits to ensure that there is no wasted energy when campers are solely inside the cabin.

The remaining electrical loads are to be determined by the users of the floating cabin. Parks Canada will inform campers of the limited energy storage available in the cabin and will instruct the campers to only use loads such as cellphone charging, laptops, tablet PCs and small camping lights, heavier loads such as coffee makers, hair dryers, toasters, etc will not be allowed. Due to the modified sine wave inverter some sensitive electronics would need to be verified compatible. HES PV has estimated these loads based on readily available consumer products however the actual load will depend on the amount of occupants.

Inverter Specifications

The inverter/charger chosen for this system is the Magnum RD1824 Modified Sine Wave Inverter, to be mounted on an e-panel inside of the battery closet on the outside of the cabin. This inverter/charger has a continuous power output rating of 1800W, which should meet the estimated power requirement of 858.4W (table 1) with room to spare for unexpected loads. This inverter is a modified sine wave inverter, this means that the ac waveform that the inverter outputs is not as smooth as a typical waveform that a person might see in their home ac outlets. The user of the cabin must be informed that the ac output may be damaging to sensitive electronics, this includes power supplies for laptop PCs.

Magnum RD1824 Inverter/Charger



RD SERIES SPECIFICATIONS

	RD2212	RD1824	RD2824	RD3924
INVERTER SPECIFICATIONS				
Input battery voltage range	9 - 16 VDC	18 - 32 VDC	18 - 32 VDC	18 - 32 VDC
Nominal AC output voltage	120 VAC ± 5%	120 VAC ± 5%	120 VAC ± 5%	120 VAC ± 5%
Output frequency and accuracy	60 Hz ± 0.1 Hz	60 Hz ± 0.1 Hz	60 Hz ± 0.1 Hz	60 Hz ± 0.1 Hz
1 msec surge current (amps AC)	60	70	100	150
100 msec surge current (amps AC)	37	40	60	90
5 sec surge power (real watts)	3700	4000	6000	8000
30 sec surge power (real watts)	3450	3300	4800	6400
5 min surge power (real watts)	3100	2850	3950	5800
30 min surge power (real watts)	2400	2400	3500	4750
Continuous power output at 25° C	2200 VA	1800 VA	2800 VA	3900 VA
Maximum continuous input current	293 ADC	120 ADC	186 ADC	260 ADC
Inverter efficiency (peak)	95%	94%	93%	93%
Transfer time	16 msecs	16 msecs	16 msecs	16 msecs
Search mode (typical)	5 watts	5 watts	5 watts	5 watts
No load (120 VAC output, typical)	20 watts	12 watts	19 watts	25 wattts
Waveform	Modified Sine Wave	Modified Sine Wave	Modified Sine Wave	Modified Sine Wave
CHARGER SPECIFICATIONS				
Continuous output at 25° C	110 ADC	50 ADC	80 ADC	105 ADC
Charger efficiency	85%	85%	85%	92%
Power factor	> 0.95	> 0.95	> 0.95	> 0.95
Input current at rated output (AC amps)	15	15	21	29
GENERAL FEATURES AND CAPABILITIES				
Transfer relay capability	2 legs at 30 A for 120 V/30 A or 240 V/60 A service			
Five stage charging capability	Bulk, Absorb, Float, Equalize (requires remote), and Battery Saver™			
Battery temperature compensation	Yes, 15 ft Battery Temp Sensor standard			
Internal cooling	0 to 120 cfm variable speed drive using dual 92mm brushless DC fans			
Overcurrent protection	Yes, with two overlapping circuits			
Overtemperature protection	Yes on transformer, MOSFETS, and battery			
Corrosion protection	Yes, PCB's conformal coated, powder coated chassis/top, and stainless steel fasteners			
Listings	ETL listed to UL1741 (USA only)			
Warranty	Two years			
ENVIRONMENTAL SPECIFICATIONS				
Temperature (Operating/Non-operating)	-20° C to +60° C (-4° F to 140° F) to -40° C to +70° C (-40° F to 158° F)			
Operating humidity	0 to 95% RH non-condensing			
PHYSICAL SPECIFICATIONS				
Dimensions (h x w x d)	13.75" x 12.65" x 8.0" (34.9 cm x 32.1 cm x 20.3 cm)			
Mounting	Shelf or wall (vents up)			
Weight	37 lb (16.9 kg)	35 lb (15.9 kg)	42 lb (19 kg)	53 lb (24 kg)
Shipping weight	46 lb (20.9 kg)	44 lb (20.0 kg)	51 lb (23.2 kg)	62 lb (28.1 kg)
Max operating altitude	15,000' (4570 m)			

Magnum Rd1824 Inverter/Charger Specifications

Battery Bank Specifications

The size of the battery bank needed is dependent on the daily loads that are needed to run as well as depth of discharge of the batteries and their temperature derating. The battery closet in the floating accommodation was design to hold 1 shelf of 4-L16 size 6V-AGM batteries for a battery bank voltage of 24V. Due to the large load draw it is highly recommended that Parks Canada investigate adding additional shelving for batteries in the battery closet. This additional shelf of batteries would be strung in parallel with the first string of batteries essentially doubling the storage capacity. If this step was taken in conjunction with reducing the amount of load on the system the systems functionality and days of autonomy could be increased.

Given the Watt-hour draw from table 1 and the tabulated system information below we can calculate the size of the battery bank needed for 1 day of continuous operation:

System Information:	
Daily Draw:	5867.1 Whr
Battery Bank Voltage	24 Vdc
Days of Cont. Operation	1
Depth of Discharge:	80%
Temp Capacity:	93.7% *

	Method	Values	Result
Amp-hours needed:	$\frac{\text{Total Draw}}{\text{Voltage}}$	$\frac{5867.1\ \text{Whr}}{24\text{V}}$	244.5 Ahr
Battery Bank Size:	$\frac{(\text{Ahr}) * (\text{Days of Operations})}{(\text{Depth of Discharge } \%) * (\text{Temp Capacity})}$	$\frac{(244.5\ \text{Ahr}) * (1)}{(0.8) * (0.937)}$	326.1Ahr

*Based on average temperature for Midland Ontario during camping season of May-Oct and Rolls Battery capacity charts, Canadian Climate Normals

Battery Specifications

The battery chosen to supply this bank is the Rolls S6-460 AGM. Under a discharge rate of 20hr we should expect the ampacity of this battery to be 415A-hr. Thus, one string of 4 S6-460s should provide enough power to the system for just over 1 day's continuous operation (~1⅓ days). For a typical offgrid system we would size the battery bank for at least 3-5 days continuous operation to ensure its functionality.

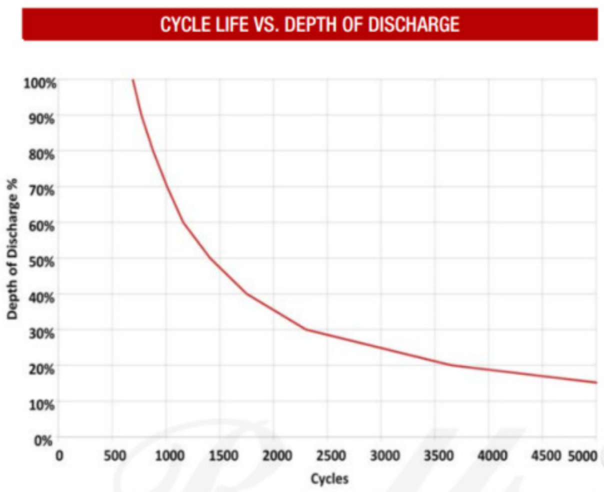
This single day of continuous operation will allow the system to function under a day of complete cloud cover, or slightly longer given partial cloud cover and low enough loads. However, given sustained cloud cover beyond this point the system will run into a higher depth of discharge and potentially shut down the system. To expand the functionality of this system

Discharge Rate Rolls S6-460

HOUR RATE:	SPECIFIC GRAVITY	CAPACITY / AMP HOUR	CURRENT / AMPS
@ 100 HOUR RATE	1.280	460	4.60
@ 20 HOUR RATE	1.280	415	20.75
@ 10 HOUR RATE	1.280	345	34.50
@ 8 HOUR RATE	1.280	335	41.88
@ 5 HOUR RATE	1.280	311	62.20

AT 77ºF / 25ºC

either electrical loads need to be removed or the size of the battery bank expanded. A generator can be used to recharge the batteries during extended periods where there is not enough sun. If space and loading would allow it, HES recommends doubling the battery bank size.



There are many factors that affect battery performance. One important characteristic is the battery depth of discharge (DoD), the more a battery is discharged, the shorter lifespan it can have. The battery bank designed for this system was designed for a maximum of 80% DoD over a single day's autonomous operation. This value is larger than the manufacturers recommended maximum of 50% DoD and will cause the batteries to have a much shorter lifespan, but reduces the size of the battery bank required. The inverter would be set to disconnect when the batteries reach the 80% discharge state. If the system continuous to draw power after its recommended day of continuous operation the batteries would exceed 80% DoD and may even be discharged completely, this would seriously hamper the lifespan of the battery or even cause it to cease functioning.

The batteries must not be left in a low state of charge for any lengthy period. When a battery is discharged the acid electrolyte is converted to water and 'sulphate' is deposited on the lead plates. This sulphate will harden if the battery is not recharged often and the sulphate will become difficult to recombine with the water. This process of is normal to the batteries charge/discharge cycle, but if the batteries are left discharge it will affect their capacity and can ruin the battery.

At the end of the camping season the battery bank should be charged and stored in aheated facility to ensure the capacity is retained for the next camping season. Routine maintenance may be required during this time and the regular camping season.

Solar Array Information

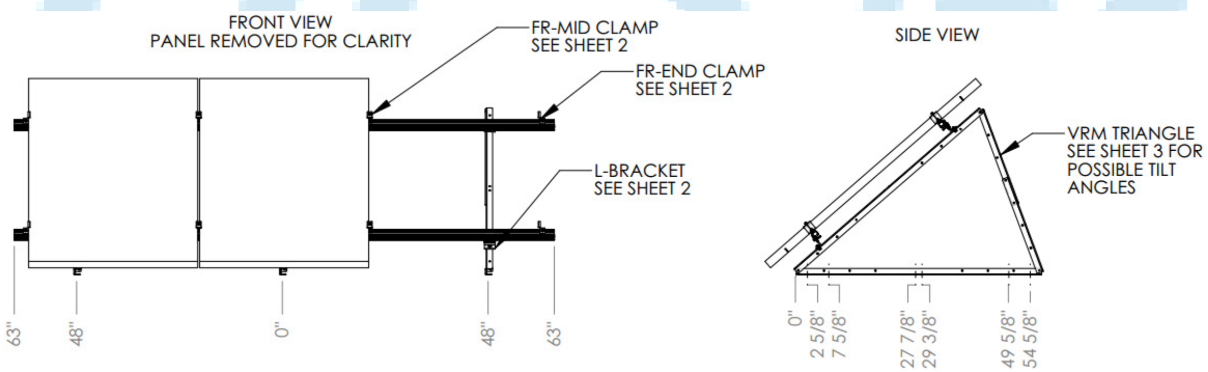
In order to provide adequate charging to the battery bank the solar array was sized to meet the daily Whr requirements. The sun hour estimate was based on NASA climate data based on the location and the average sun hour value for the camping season for solar modules at a tilt of 53 degrees and an azimuth (True South) of 0 degrees south. It is assumed that the solar modules will be oriented solar south wherever the floating accommodations are located.

SOLAR ARRAY	
Daily load draw:	5867.1Whr
Average Incident Sun-hours per day	4.18*
Array losses	5%
Actual Array size (Watts)	1,710

	Method	**Values**	**Result**
Array Size:	$\frac{(\text{Daily load draw}) * (1 + \text{Array losses})}{(\text{Incident Sun} - \text{Hours})}$	$\frac{5867.1\ \text{Whr} * 1.05}{(4.18)}$	1473.8W

* Average sun hours in the month of October used as worst case for solar irradiation,NASA Surface meteorology and Solar Energydataset

Due to space constraints on the top of the floating accommodation roof initial estimates show that we are limited to 2 sets of VRM3 (vertical roof mounts) for use with 60- cell modules. The Stark SM285-60P solar module was chosen as the 60 Cell solar module for this design. This gives a total module count of 6 modules and a total array capacity of 1,710W. These modules will be run in 2 strings of 3 into a MNPV3 combiner box and then into the charge controller.



VRM3- Roof Mount for 60 Cell Solar Modules

Stark Modules // SM-285-60M

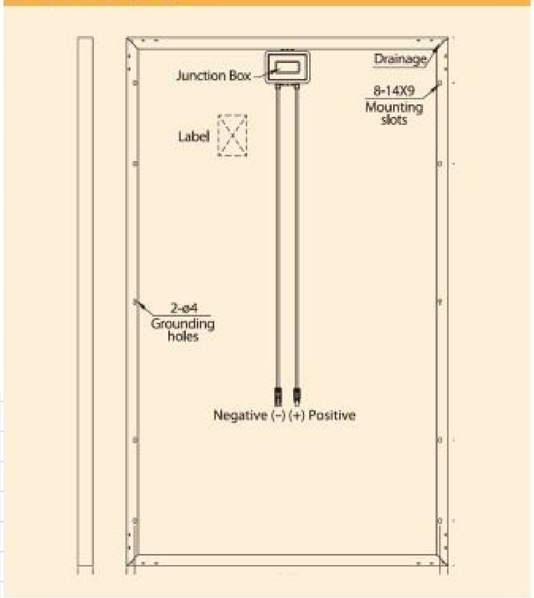
High Efficiency Solar Modules built for Canada

ELECTRICAL CHARACTERISTICS	
Module	SM-285
Max Power (Pmax)	285 W
Open Circuit Voltage (Voc)	38.95 V
Maximum Power Voltage (Vpm)	33.06 V
Short Circuit Current (Isc)	9.25 A
Maximum Power Current (Ipm)	8.62 A
Max Series Fuse Rating	15 A
Temperature Coefficients of PM	-0.47% / °C
Temperature Coefficients of Voc	-0.35% / °C
Temperature Coefficients of Isc	+0.04%/ °C

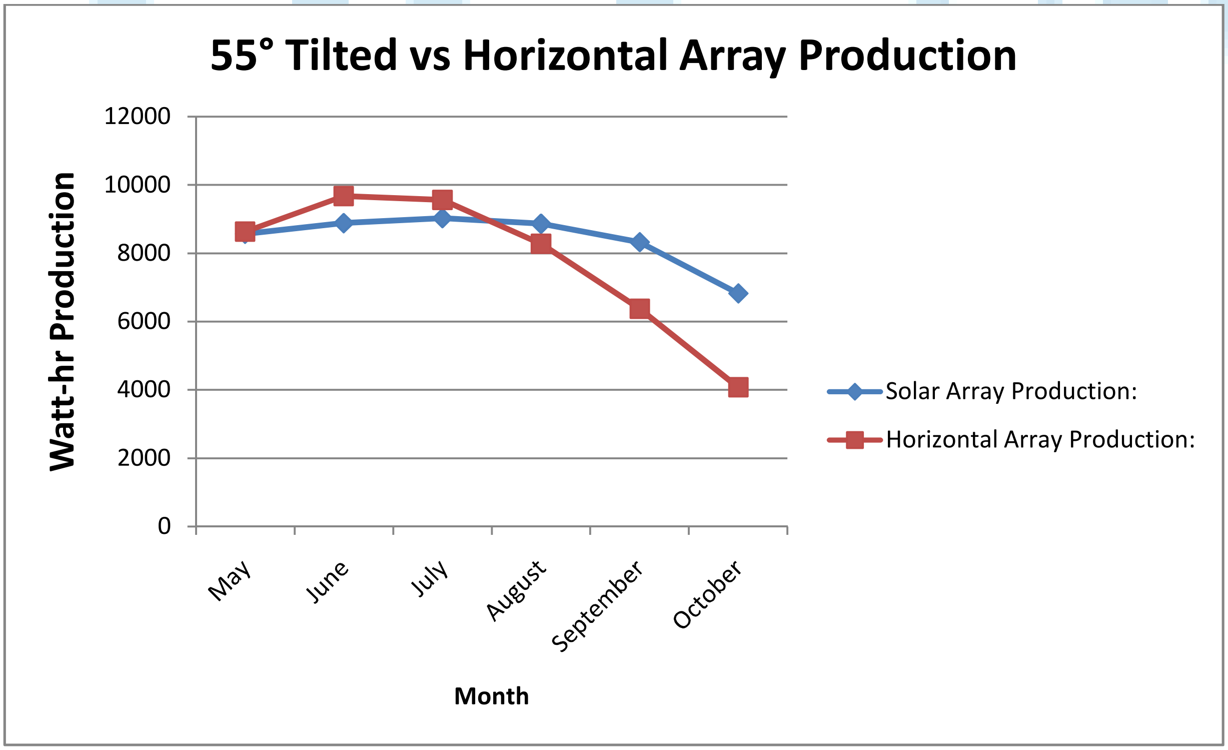
STC - Standard Test Conditions: Irradiation 1000 W/m² - Air mass AM 1.5 - Cell temperature 25 °C
Calculated using maximum power

3x SM285-60P String Sizes	
Power:	855W
Voc:	116.85V
Vpm:	99.18V
Isc:	9.25A
Ipm:	8.62A

DIMENSIONS



Stark SM285-60P Solar Module Specifications



Charge Controller Specifications

HES PV has determined that the Midnite Classic 150 charge controller is an adequate model for this system. This model will be mounted onto the e-panel along with the inverter inside the battery closet. The specifications of this model are as follows:

Classic and Classic Lite 150, 200 or 250	
Nominal Battery Voltage	12 Through 72 volts on Classic's. Lite requires PC or MNGP for advanced feature programming
Maximum Output Current	Classic 150 and 150 Lite = 96A on 12V, 94A on 24V and 86A on 48V battery Classic 200 and 200 Lite = 79A on 12V, 78A on 24+48V and 65A on 72V battery Classic 250 and 250 Lite = 61A on 12V, 62A on 24V, 55A on 48V and 43A on 72V battery
PV Open Circuit Voltage VOC *(NOTE: See HyperVOC at bottom)*	Classic150 = 150V + HyperVOC (battery voltage up to 48V) *Example 150V + 48V = 198VOC* Classic200 = 200V + HyperVOC (battery voltage up to 48V) Classic250 = 250V + HyperVOC (battery voltage up to 48V) *(NOTE: See HyperVOC at bottom)*
Power Conversion Efficiency	98% (Typical system)
Maximum Stand-By Self-Consumption (12V)	2.8W - 4W
Reverse Current At Night	Zero - Internal relay for reverse current
Low Battery Voltage	Low Battery voltage disconnect and re-connect of loads fully programmable with 2 Auxiliary outputs to control external load disconnect /re-connect switches
Hyper VOC *(NOTE: See HyperVOC at bottom)*	Standard all models - Extended VOC range for cold climates
Arc Fault Protection	Standard on Classic, 0.25 second detect and trip speed - Not available on the Lite
Ground Fault Protection	Standard all models - resettable, no fuse to blow
Charging Regulation	Bulk, Absorb, Float as well as Equalization
Battery Voltage Regulation Set Points	10-100VDC
Equalization Charging	Adjustable Voltage and Duration, Manual or Auto
PV Reverse Polarity	Protected to Max VOC
Battery Reverse Polarity	Fully protected
Battery Over Voltage	Fully protected
Battery Short Circuit	Fully protected
Battery Temp Compensation	Automatic when BTS is installed, Adjustable mV per degree C per 2V cell
Programmable Auxiliary Control Output	2 Auxiliary outputs, Aux1 can be 12V out or dry contact, Aux2 is 12V out or Logic IN
Graphic Display	Graphical display - MNGP (NOTE: MNGP is an option on the Classic Lites)
Networking Cabling	Standard 4 conductor phone cable, no hub needed
Communications	RS232, Ethernet and ModBus openly published protocol
Remote Display	Display (MNGP) can be relocated and a second display can be added
Remote Monitoring And Control	Local Application software included allows viewing and control from the network or over the Internet. MyMidNite.com - online status monitoring
Internet Ready	All models
Data Logging	380 days of daily history, 24 hours of data at 5 minute intervals
Wind And Hydro Applications	Standard on all models, requires a PC or MNGP on the Lite
Positive Ground Applications	Requires 2 pole input and output breakers
Operating Temperature	Minimum of -40C to 50C - Controller will auto derate as temperature rises above 25C
Environmental Rating	Indoor type 1
Conduit knock Outs	Single 1" conduit (35.05mm) on left and right sides. Two 1" conduit (35.05mm) on bottom. Two 3/4" conduit (27.76mm) on back.
Warranty	5 Year standard
Weight & Dimensions	12 Lbs. (5.45 kgs) - 14.9" x 6" x 4" (378mm x 152mm x 102mm)
Shipping Dimensions HxWxD	19" x 8.5" x 5.7" (482.6mm x 215.9mm x 144.78mm)
Options	MNGP graphical display, 3ft networking cable (NOTE: MNGP standard with Classic and optional with the Classic Lite)
Certifications	Listed by ETL for US & Canada, CE Certified, FCC Class B

Considerations

HES PV would recommend investigating the loads further to see if it can be reduced or the battery bank increased. The roof area would need to be able to handle the mounting system and the dead load of the solar modules. A generator shore plug could be added to the system to make it easy to plug into a portable generator to charge the system during times of heavy use or lack of sun.