# 45 KWH LFP Whole House UPS

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NTMS Presentation
December 7, 2024

# Whole House UPS

- Or – How to spend money with dubious return
- Sturgeon's Law* – 90% of Everything is Crap

*Theodore Sturgeon (1918-1985) - Science Fiction, Fantasy and Horror Author

# Agenda

- Concept / Requirements
- NEC / UL Standards that are applicable
- Project Timeline
- Inverter Types
- Construction photos/details
- LFP battery BMS (Battery Management Systems) settings.
- LFP surge current issues when starting A/C compressors
- Supercap installation / cautions
- Pre-charge circuits
- Operational usage data
- Lessons learned
- LFP battery module design and setup
- Links to good sources of information/ Suppliers

# 45 KWH LFP Whole House UPS Objectives

- Power all house loads from 20kw inverters
- Have 40+ kwhr 48V DC LiFePO4 battery storage system with BMS (battery management system)
- Have optional 10kw Solar arrays
- Have selective load shedding capability to run off-grid
- Control and monitoring system

# Initial Naive Assumptions

- Batteries under 60 volts DC are Class 2 and the code doesn't really care about them – FALSE – Class 2 is under 100VA power and batteries are now an Energy Storage System. See UL9540
- An LFP battery pack with 400A 52Vdc will be sufficient for the house – FALSE – Surge current issues starting motors/compressors
- You can do anything with your house in Texas without inspectors – FALSE – what if you ever want to sell the house?
- You can manage the system when you are out of town – Partly FALSE – how do you tell the difference between a house power failure and an internet failure?
- Battery packs in parallel just work – FALSE – BMS SOC issues
- Salesmen are honest – FALSE – by inspection

# Standards

- Anti Islanding UL Standard 1741
  - In the event of a power failure on the electric grid, it is required that any independent power-producing inverters attached to the grid turn off in a short period of time. This prevents the DC-to-AC inverters from continuing to feed power into small sections of the grid, known as “islands.” Powered islands present a risk to workers who may expect the area to be unpowered, and they may also damage grid-tied equipment.
- Energy Storage System ESS (>1kwh)
  - NEC Article 706
  - UL Standard 9540
    - https://www.ul.com/news/ul-9540-energy-storage-system-ess-requirements-evolving-meet-industry-and-regulatory-needs
    - Certifies a particular lithium battery in combination with a particular inverter brand and type. At the time this is written UL9540 is the Holy Grail of certifications; installing a combo of battery and inverter that is UL9540-listed will give you that magic-carpet-like ride through electrical inspection!
- Stand-Alone Power System NEC Article 710
- Labeling NEC section 690

# Project Timeline

- Oct 12 2022 – Sunny Island inverters ordered (x2)
- Oct 16 2022 – SI inverters arrive (x2)
- Oct 18 2022 – LFP Battery order placed
- Jan 4 2023 – LFP batteries arrive
- Jan 2023 – System planning and prototyping
- Feb 17 2023 – Outside entrance work started
- Feb 2 2023 – More SI inverters ordered (+x2)
- Feb 13 2023 – SI inverters arrive (+x2)
- Mid-Apr 2023 – garage wall reinforcement
- Apr 19 2023 – 4x SI inverters mounted
- May 6 2023 – Garage inverter wiring complete
- May 31 2023 – Conduit and wiring runs to service entrance complete
- June 11 2023 – House running off-grid except at night when batteries charge
- July-September 2023 – A/C softstart units installed
- Nov 7 2023 – 1000A shunt installed
- March 2024 – 4 channel, 300A current sense bread board built, measurements taken
- October 2023 – Supercap ordered
- March 2024 – Supercap delivered
- April 2024 – second supercap ordered and received
- May 6 2024 – Switched to TXU Free nights and Solar Days plan

# Inverter Types and Concepts

- Grid-tie vs off-grid vs hybrid inverters
- Importance of anti-islanding capability
- Frequency Shift Power Control in AC coupled systems

# Inverter Types and Concepts

- **Grid-Tied Solar Inverter**
  - Grid-tied inverters are permanently connected to the utility grid
  - They convert solar-generated DC into AC compatible with the grid’s frequency and voltage
  - They shut down when the grid goes down to protect grid linemen (anti-islanding)
- **Off-Grid Solar Inverters**
  - Part of a standalone system, typically paired with battery storage
  - Used in remote locations, providing a self-sufficient energy solution
- **Hybrid Solar Inverters**
  - Combine the functionalities of grid-tied and off-grid systems
  - Feed energy into the grid, store it in batteries, and provide backup power during outages
  - Allows energy independence while still being connected to the grid

# Background

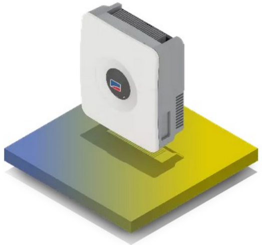
- Why SMA inverters?
- AC Coupled Multimode System
  - Best flexibility
- SMA largest Germany Solar Inverter mfg - $2Bn Sales
  - Known for being bullet proof
- Familiarity with 1st Gen capability from startup work in 2010-12
- Visited SMA Germany in Dec 2010

# SMA Current Gen Energy Storage Solutions

Benefits    Components    System details    Other solutions    Next steps

### PV Modules

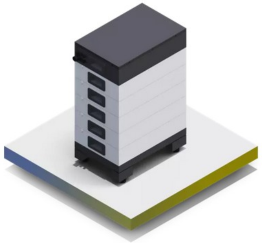
Optimized for your homes solar power needs



### Sunny Boy Smart Energy

The center of the SMA Home Energy Solution, this groundbreaking hybrid inverter combines the functions of a PV and battery inverter into a single unit, keeping electrical upgrades to a minimum

**Learn more →**



### BYD Premium HVL Battery-Box*

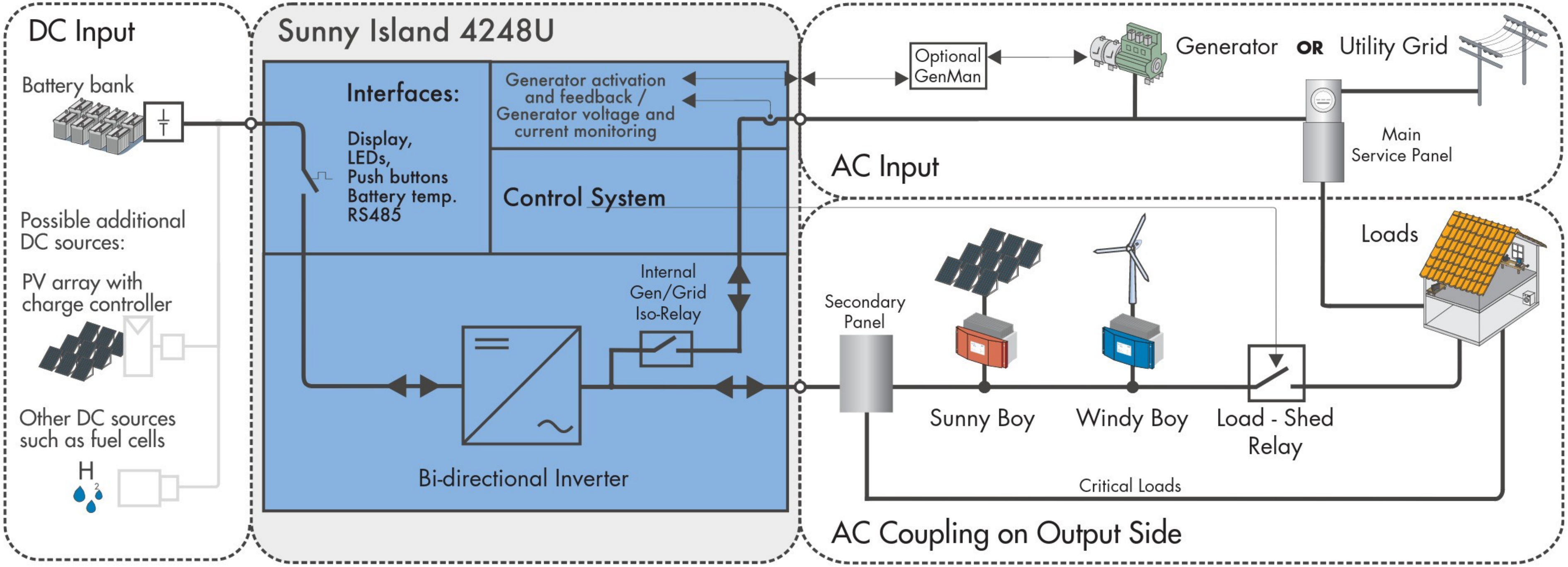
12.0, 16.0, 20.0, 24.0, 28.0, 32.0 (UL9540)
This BYD battery enables intermediate storage of unused solar energy and makes it available on demand when you need it the most.

*not sold by SMA

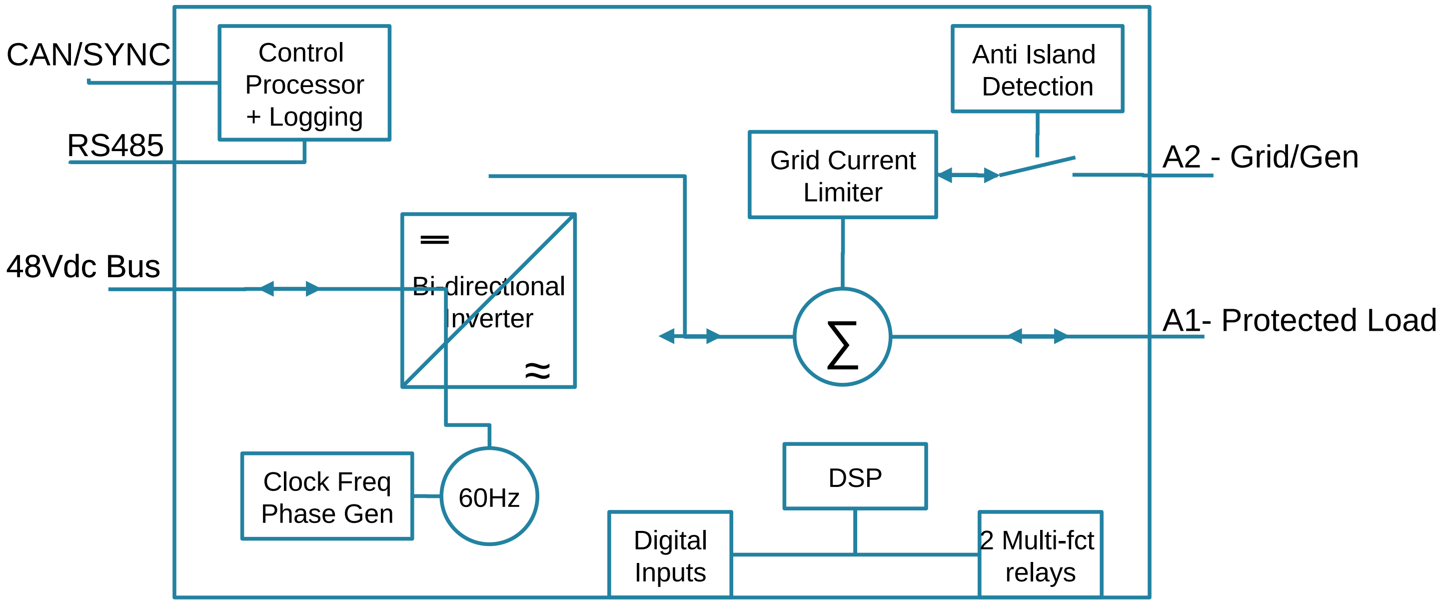
### SMA Energy App

The Energy app will give you the most important information about your energy system including production and consumption

# 1st Gen SMA System Capabilities

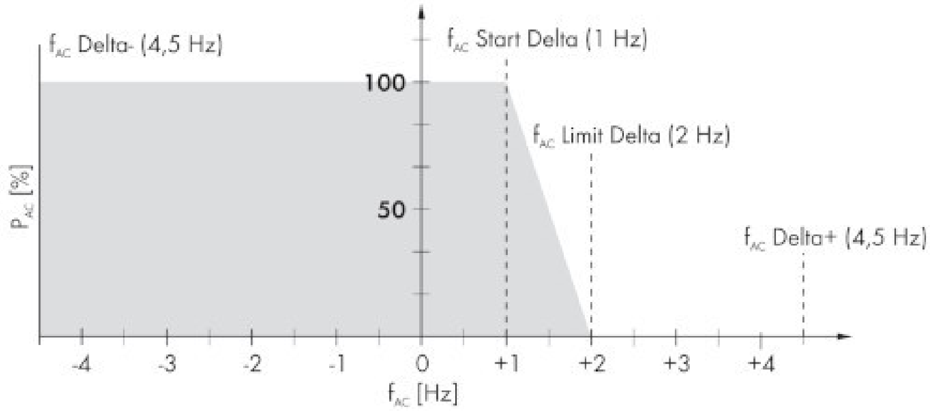


# Sunny Island
# Notional Block Diagram



# Frequency Shift Power Control

- FSPC allows a Sunny Island inverter to limit power output of Sunny Boy Photovoltaic inverters connected to the AC side
- Needed when Sunny Island battery is fully charged and the (solar) power available from the PV array exceeds the power required by the connected loads
- To prevent the excess energy from overcharging the battery, the Sunny Island changes the frequency  the AC output. This frequency adjustment is analyzed by the Sunny Boy.
- As soon as the power frequency increases and exceeds a defined value "fAC Start Delta", the Sunny Boy limits its power accordingly.



## 22.2 Sunny Island 6048-US

| Output Data | | SI 6048-US-10 |
|---|---|---|
| Nominal AC voltage (adjustable) | $V_{AC, nom}$ | 120 V (105 V to 132 V) |
| Nominal frequency | $f_{nom}$ | 60 Hz (55 to 65 Hz) |
| Continuous AC power at 77°F (25°C) | $P_{nom}$ | 5,750 W |
| AC power for 30 minutes at 77°F (25°C) | $P_{30min}$ | 7,000 W |
| AC power for 1 minute at 77°F (25°C) | $P_{1min}$ | 8,400 W |
| AC power for 3 seconds at 77°F (25°C) | $P_{3sec}$ | 11,000 W |
| Continuous AC power at 104°F (40°C) | $P_{nom}$ | 4,700 W |
| AC power at 104°F (40°C) for 3 hours | $P_{3h}$ | 5,000 W |
| Continuous AC power at 122°F (50°C) | $P_{nom}$ | 3,500 W |
| Continuous AC power at 140°F (60°C) | $P_{nom}$ | 2,200 W |
| Nominal AC current | $I_{AC, nom}$ | 48.0 A |
| Maximum current (peak value) for 60 ms | $I_{AC, max}$ | 180 A |
| Total harmonic factor of the output voltage | $K_{VAC}$ | < 3% |
| Power factor cos φ | | –1 to +1 |

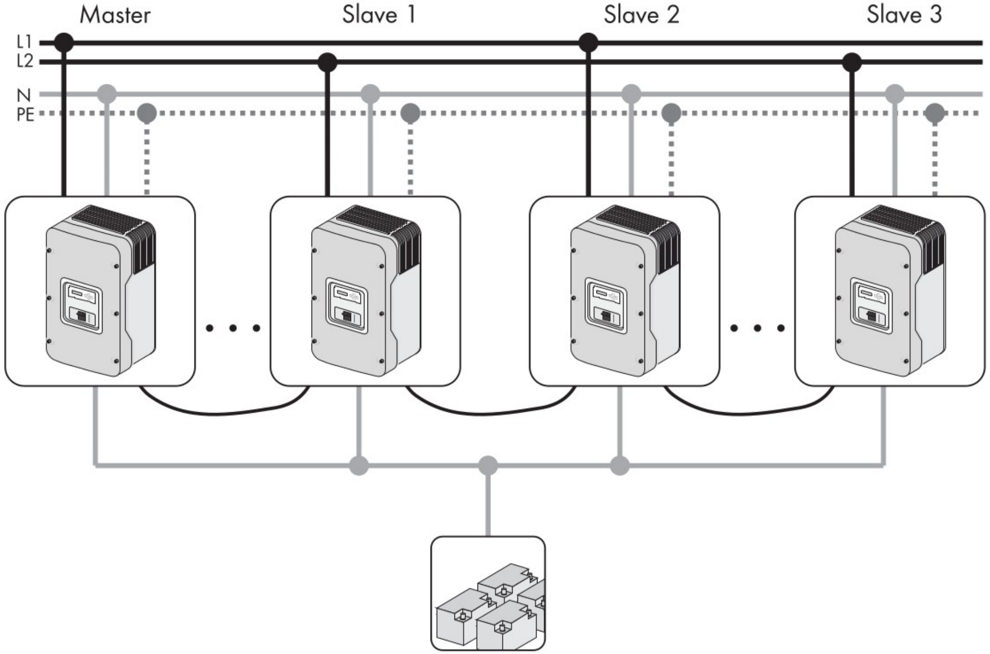
| Input Data | | |
|---|---|---|
| Input voltage (adjustable) | $V_{AC, ext}$ | 120 V (80 V to 150 V) |
| Input frequency (adjustable) | $f_{ext}$ | 60 Hz (54 Hz to 66 Hz) |
| Maximum AC input current (adjustable) | $I_{AC, ext}$ | 56 A (0 A to 56 A) |
| Maximum input power | $P_{AC, ext}$ | 6.7 kW |

| Battery Data | | |
|---|---|---|
| Battery voltage (range) | $V_{Bat, nom}$ | 48 V (41 V to 63 V) |
| Maximum battery charging current | $I_{Bat, max}$ | 140 A |
| Continuous charging current | $I_{Bat, nom}$ | 110 A |
| Battery type | | Lead-acid battery: VRLA/FLA/<br>NiCd battery<br>Lithium-ion battery |
| Battery capacity for lead-acid batteries and NiCd batteries | $C_{Bat}$ | 100 Ah to 10,000 Ah |
| Battery capacity for lithium-ion batteries | $C_{Bat}$ | 50 Ah to 10,000 Ah |

# Configuration Implemented

**Double Split-Phase System, 240 Vac, up to 24 kW**

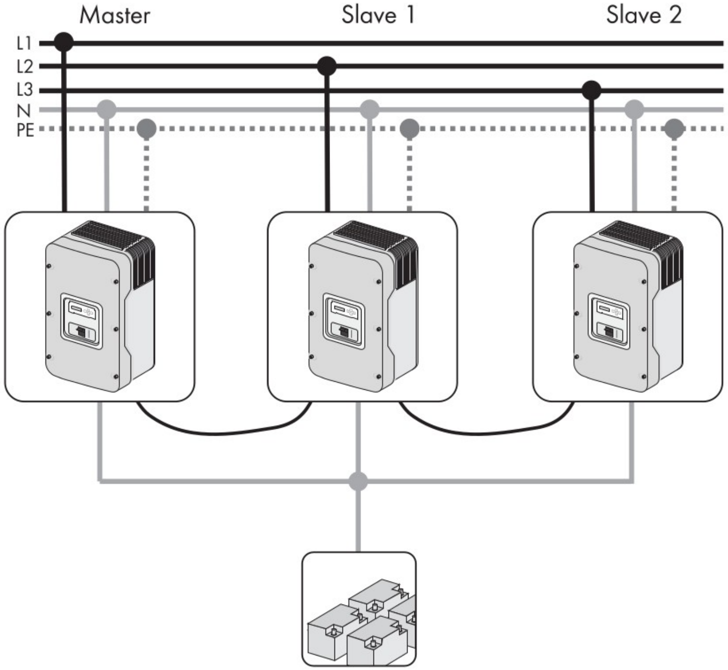
4 Sunny Island of types SI 4548-US-10 / 6048-US-10. Only Sunny Island inverters of the same type must be used on one line conductor. L1 and L2 may be installed with different types (e.g.: L1 with 2 x SI 4548-US-10 und L2 with 2 x SI 6048-US-10).*



# Interesting 3 Phase Option

**Three-Phase System, 120/208 Vac, up to 18 kW**

3 Sunny Island of types SI 4548-US-10 / 6048-US-10.*



# Questions on this section?

# Construction

# Original Service Entrance


- 200A Square-D HOM Service
- 2 remote subpanels / conduit
  - Garage
  - Sauna
  - West A/C conduit run
- 30A Manual Xfer Switch (lower right)
- No access to back side of service panel due to fireplace

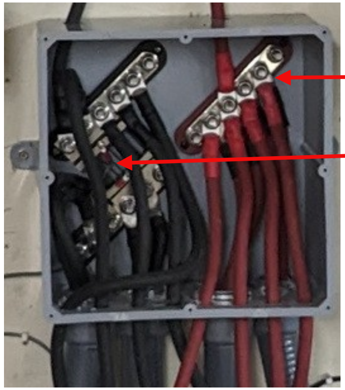
# New Load Panel/ Svc Entrance Installation

- Grid panel
- Inverter House panel
- Gen xfer switch
- Inverter cutoff lockout

# Garage Installation

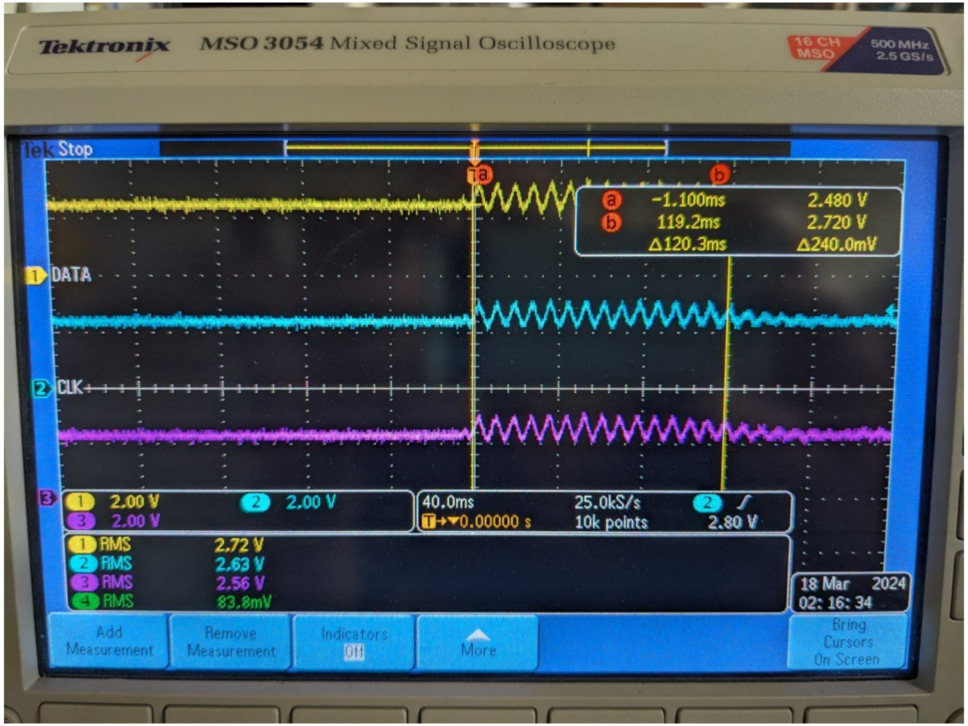

- 260F SuperCaps – AC start
- 4x Sunny Island – 2 per phase
- Inverter input breaker
- Pre-Charge circuit
- Inverter output breaker
- DC Bus bars
- ennexOS Datamanager M
- 200A Class T DC fuses
- Lab PS 5A 60Vdc
- 4x 11.6kwh LFP 52v packs

# DC Bus Bar



- 300A Bus Bar
- 1000A Current Shunt
  - SI DC Current Sensor

# A/C Surge Current

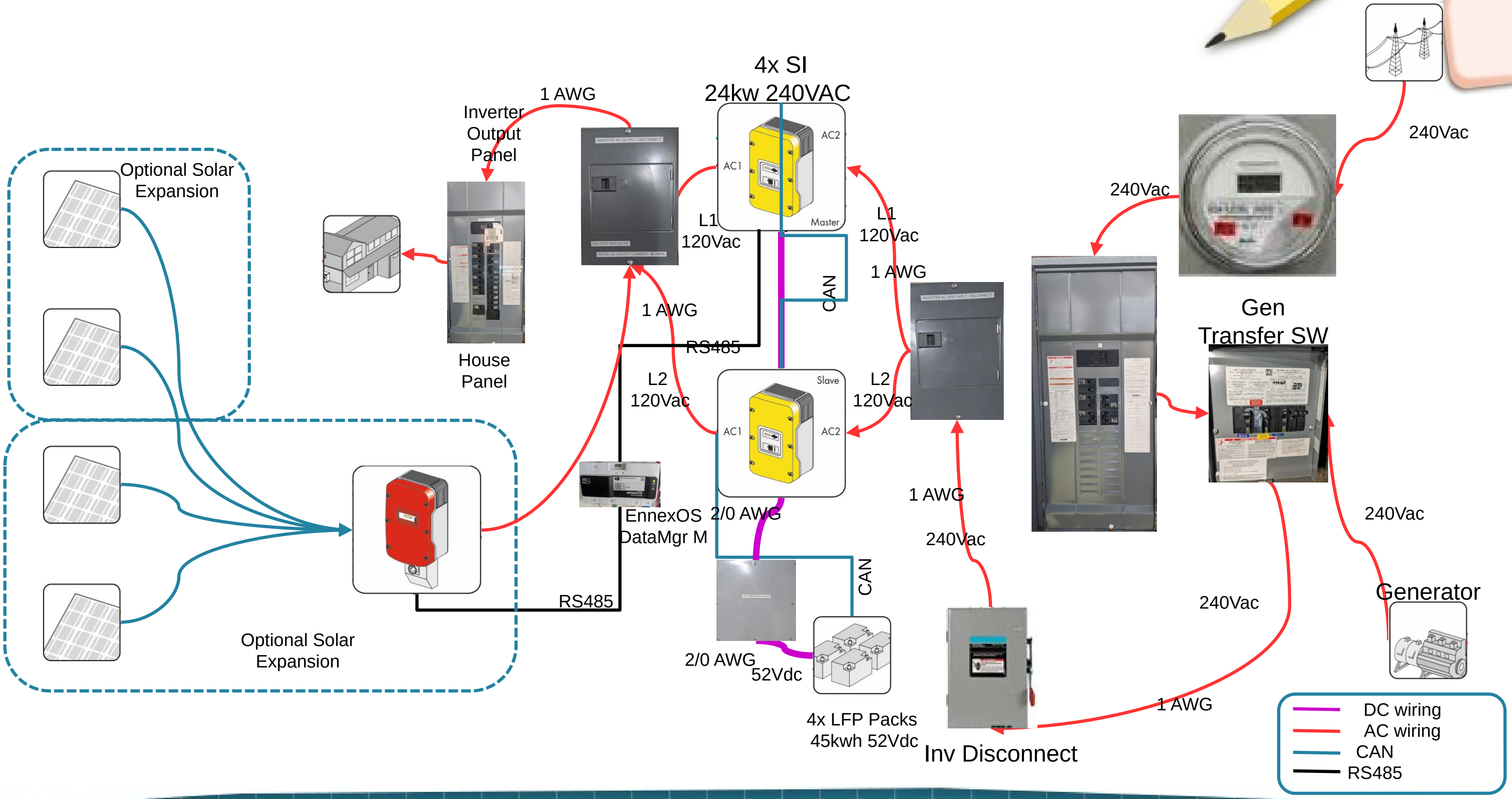



- 120 msec surge 5 Ton Compressor start
- 7-8 60Hz cycles
- 140A 240Vac peak surge
- 650A 52Vdc peak surge
- LFP rated current 100A
  - x4=400A total continuous
- LFP stated surge was 200A/pack
  - BMS limits actually set at 110A for 1 sec

# SuperCap / Precharge


- 2x130F Eaton Supercaps
- 260F is a dead short initially
- DC Breaker - 250A
- 18Ω 200 Watt Resistor
  - RC=78 minutes
  - ~6 hrs to charge
- Used only if caps need to be removed/reconnected to DC bus
- Switches PreChg res in/out

# System Diagram



# 4 kw Generator Use May 2024 Power Failure


- 2 Day May 2024 Grid Failure
- UPS kept house up w/ AC
- Used gen during day to charge batteries
- Nights were noise free
- Hosted elderly neighbors
- Gas cost 1.64/kwh
- Run off-grid indefinitely assuming gas stations open

# Attic Conduit Elbows

- 1.5” Rigid Conduit
- 2x90 degree elbows provide 24” rise and turns needed

# Conduit Pipe Threading

- 1.5” Rigid Conduit
- Manual Pipe cutting / threading
- Good workout

# Wiring in Progress


- 1 AWG L1/L2 Wiring
- 2/0 AWG Battery Wiring
- 4” Raceway wiring Channel
- 1.5” Rigid conduit main runs
- 2” EMT Conduit

# Questions on this section?

# LFP Batteries

- Lithium iron phosphate ($LiFePO_4$)

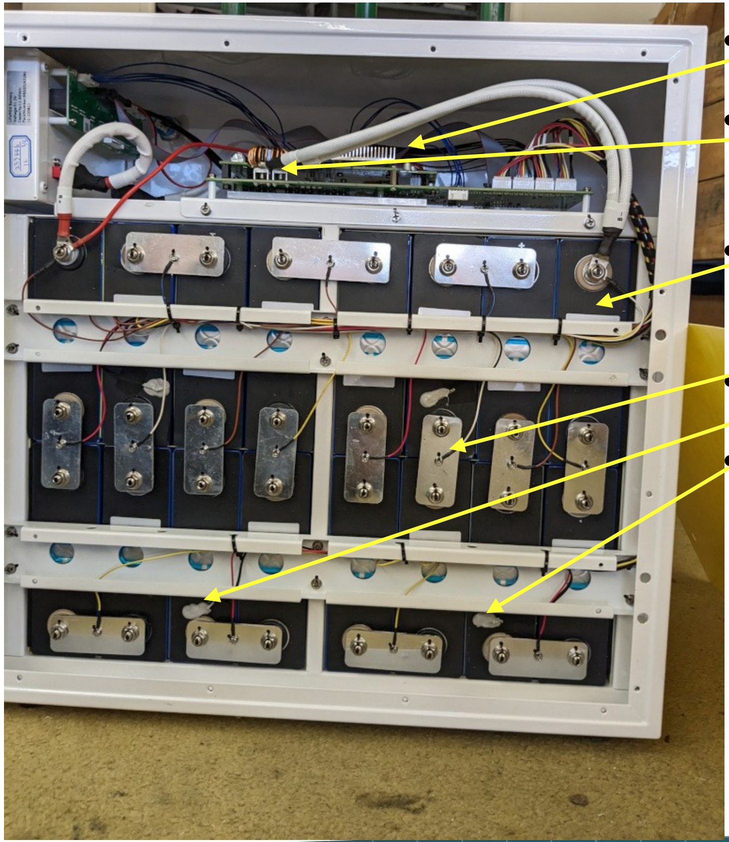
# RJ Lithium Battery Specs

| | |
|---|---|
| Model | RJ-LFP48228-FB |
| Norminal Power(KWh) | 11.6 KWh |
| Nominal Capacity(Ah) | 228Ah |
| Norninal Voltage(V) | 51.2V |
| Material Type | Lithium Battery (LiFePO4) |
| Dimensions (mm) | 600*302*550mm (Customized) |
| Weight(Kg) | 93 Kg |
| Discharging Voltage(V) | 40~58.4 V |
| Max Charging | 100A |
| Continuous Discharging (A) | 100A |
| Peak Discharging (A) | 200A |
| Expansibility | 116KWh |
| Installation Methode | Wall / Floor Mounted |
| Communication Port(Optional) | RS485 / CAN |

# RJ Lithium Battery Specs

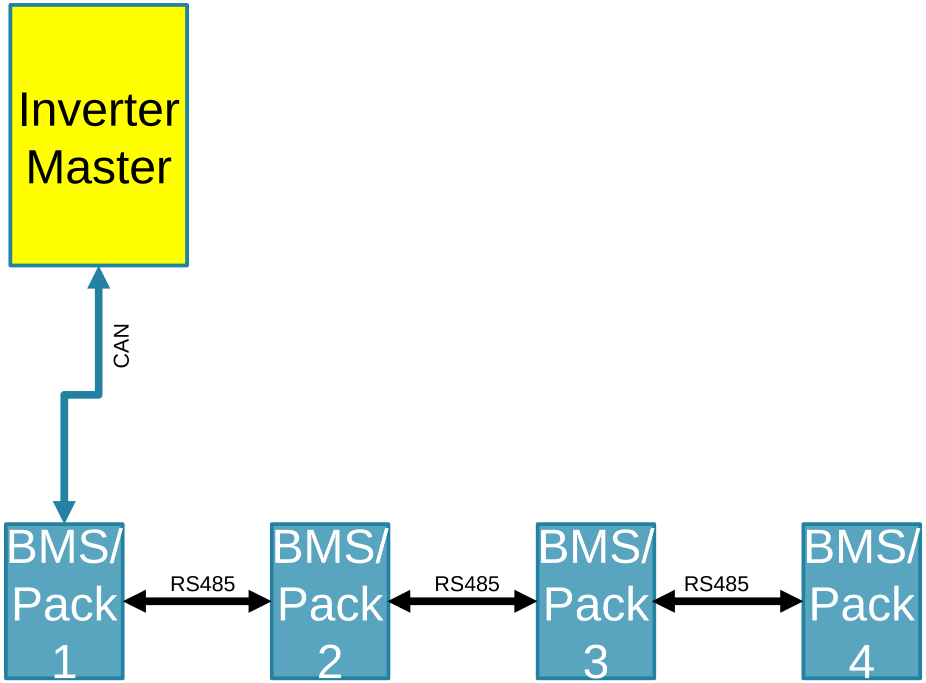
| | |
|---|---|
| Working Temperature(℃) | -20~65℃ |
| Humidity | 0-95% RH |
| IP Grade (IP) | 0-95% RH |
| Altitude | ≤3000m |
| Authentication Level | TuV/CE/UN38.3 |
| Inverter | SMA/Deye/Growatt/Schneider/Outback/Victron and so on |
| Design Life(year) | 30+ years |
| Cycle Life (cycle) | >8000Times (100%DOD) |

# RJ Lithium Batteries



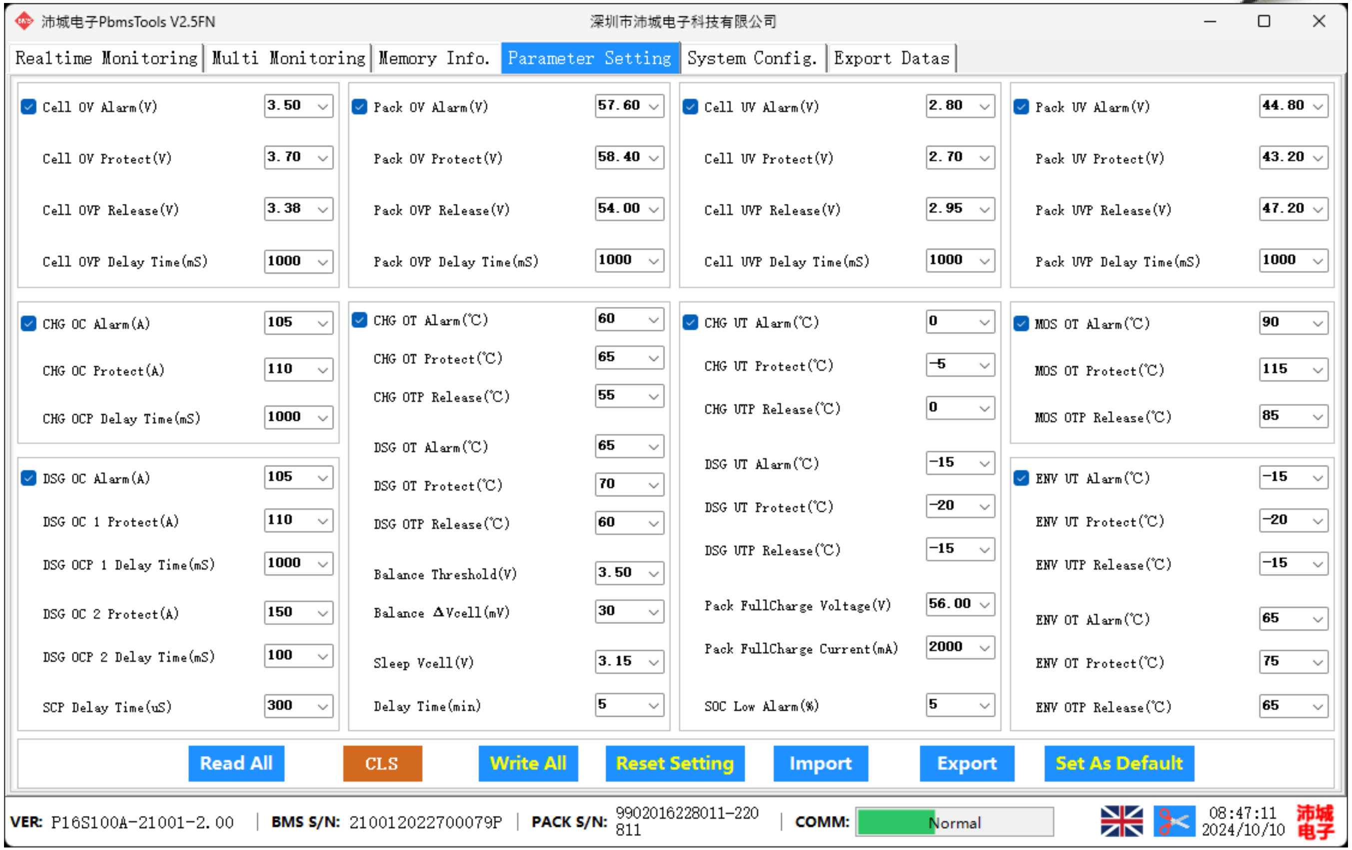
- BMS
- Negative lead safety interruption
- 16 Prismatic LFP cells in Series (16S)
- Voltage sensors for each cell
- Cell Temp Sensors

# Multipack BMS Control Architecture

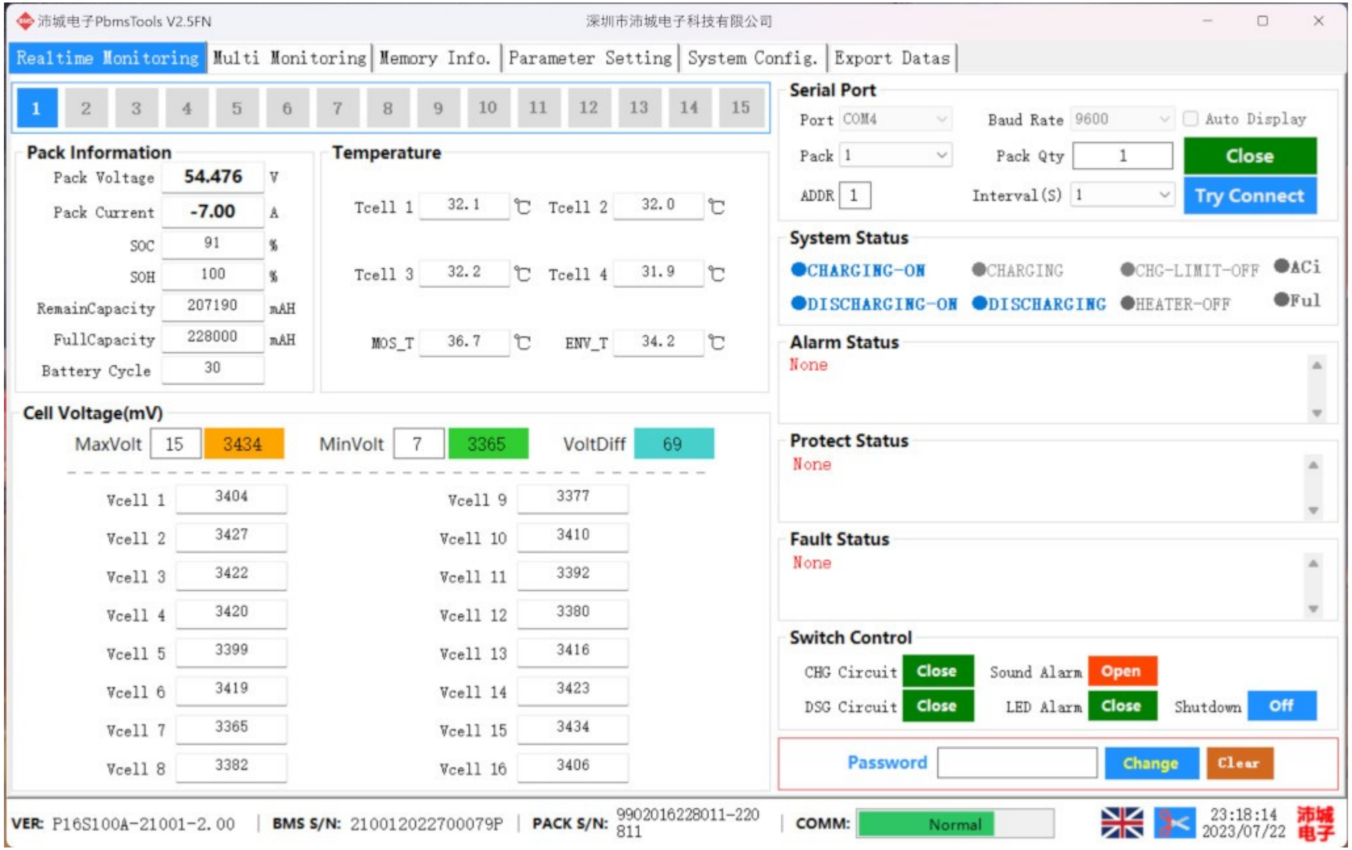



- Pack 1 is master BMS
- Responsible for Inv CAN Comm
- Consolidates pack status
  - SOC, Alarms,etc
- Coordinates pack cell balancing

# BMS Limit Settings

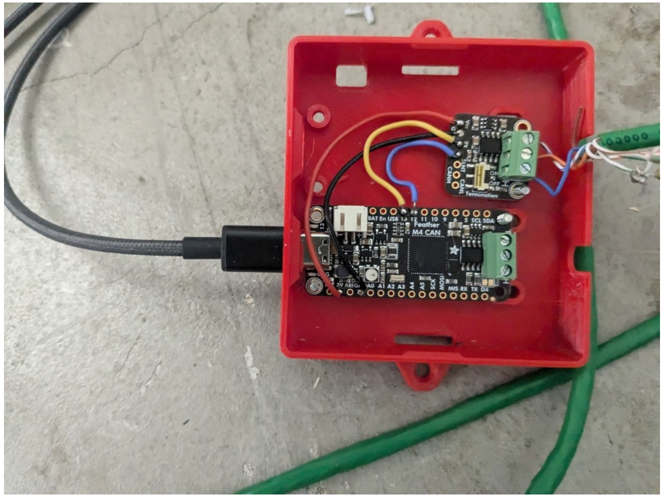


# BMS Pack Status



# Battery SOC Balancing

# CAN Bus Sniffer



- Adafruit Feather M4 CAN
  - Dual CAN bus
- Sniffed CAN-BMS communications
- Plan to modify CAN traffic between BMS and Inverter
  - Copy most of traffic on BMS CAN to Inverter CAN
  - Modify BMS charge current requests

# Sniffer Interrupt Driven Packet Processing

```
static void callBackForStandardSingleFilter (const CANFDMessage & inMessage ) {

  switch (inMessage.id) {

case 0x305:
      // SI read back Voltage / Current / Temp / SOC - 8 bytes of data
      // 16 bits, signed int, 2s complement
      // V in 0.1V, A in 0.1A, T in 0.1C, SOC in 0.1%

        val_unsigned = inMessage.data_s16[0] ;
        itoa(val_unsigned, si_batt_volts, 10);
        div10(si_batt_volts);

        val_signed = inMessage.data_s16[1] ;
        if ( val_signed > 0x7FFF ) val_signed = val_signed - 0x10000;
        itoa(val_signed, si_batt_current, 10);
        div10(si_batt_current);

        val_signed = inMessage.data_s16[2] ;
        if ( val_signed > 0x7FFF ) val_signed = val_signed - 0x10000;
        itoa(val_signed, si_batt_temp, 10);
        div10(si_batt_temp);

        val_signed = inMessage.data16[3] ;
        if ( val_signed > 0x7FFF ) val_signed = val_signed - 0x10000;
        itoa(val_signed, si_batt_soc, 10);
        div10(si_batt_soc);
        // print raw values
        Serial.print("0x "); Serial.print(inMessage.id, HEX) ;
        Serial.print(", ") ; Serial.print(inMessage.data[0], HEX) ;
        Serial.print(", ") ; Serial.print(inMessage.data[1], HEX) ;
        Serial.print(", ") ; Serial.print(inMessage.data[2], HEX) ;
        Serial.print(", ") ; Serial.print(inMessage.data[3], HEX) ;
        Serial.print(", ") ; Serial.print(inMessage.data[4], HEX) ;
        Serial.print(", ") ; Serial.print(inMessage.data[5], HEX) ;
        Serial.print(", ") ; Serial.print(inMessage.data[6], HEX) ;
        Serial.print(", ") ; Serial.println(inMessage.data[7], HEX) ;
        // print interpreted values
        snprintf_P(msgString,
                   MSG_BUFFER_SIZE,
                   PSTR("ID: 0x305, SI_Volts=%s, SI_Current=%s, SI_Temp=%s, SI_SOC=%s%%"),
                   si_batt_volts, si_batt_current, si_batt_temp, si_batt_soc);
        Serial.println(msgString);

        break;

      case 0x306:
        // SI read back SOH / Charging Proc / SI operation state / SI Error msg / SI batt chg volts
        // U16 / U8 / U8 / U16 / U16 / U16 / U16
```

- ACANFD_FeatherM4CAN is a driver for the two CAN modules of the Adafruit Feather M4 CAN microcontroller
- The driver supports many bit rates, as standard 62.5 kbit/s, 125 kbit/s, 250 kbit/s, 500 kbit/s, and 1 Mbit/s.
- Interrupt driven option based on packet id

```
// 0x351:
// Battery charge voltage, charge/discharge current limit - 6 bytes of data
// 16 bits, unsigned int, signed int, signed int
// V in 0.1, A in 0.1
case  0x351:
  val_unsigned = inMessage.data16[0] ;
  itoa(val_unsigned, batt_charge_v, 10);
  div10(batt_charge_v);

  val_signed = inMessage.data_s16[1] ;
  if ( val_signed > 0x7FFF ) val_signed = val_signed - 0x10000;
  itoa(val_signed, batt_charge_a, 10);
  div10(batt_charge_a);

  val_signed = inMessage.data_s16[2] ;
  if ( val_signed > 0x7FFF ) val_signed = val_signed - 0x10000;
  itoa(val_signed, batt_discharge_a, 10);
  div10(batt_discharge_a);

  val_unsigned = inMessage.data16[3] ;
  itoa(val_unsigned, batt_discharge_v, 10);
  div10(batt_discharge_v);

  snprintf_P(msgString,
             MSG_BUFFER_SIZE,
             PSTR("ID: 0x351, ChargeV=%s, ChargeA=%s, DischargeA=%s, DischargeV=%s"),
             batt_charge_v, batt_charge_a, batt_discharge_a, batt_discharge_v);

  Serial.println(msgString);
  break;
```

# SI Inverter-BMS CAN Traffic

**Data from external BMS (Orange mandatory values):**

| Byte | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| CAN-ID | 0 | | 1 | | 2 | | 3 | |
| 0x351 | Battery charge voltage | | DC charge current limitation | | DC discharge current limitation | | discharge voltage | |
| 0x355 | SOC value | | SOH value | | HiResSOC | | | |
| 0x356 | Battery Voltage | | Battery Current | | Battery Temperature | | | |
| 0x35A | Alarms | | | | Warnings | | | |
| 0x35B | Events | | | | | | | |
| 0x35E | Manufacturer-Name-ASCII | | | | | | | |
| 0x35F | Bat-Type | | BMS Version | | Bat-Capacity | | reserved Manufacturer ID | |

For eventual monitoring purposes Sunny Island sends out every second following process values (read only). Note that battery voltage and battery current are Sunny Island measured values.

| Byte | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| CAN-ID | 0 | | 1 | | 2 | | 3 | |
| 0x305 | Battery voltage | | Battery current | | Battery temperature | | SOC battery | |
| 0x306 | SOH battery | | Charging procedure | Operating state | active Error Message | | Battery Charge Voltage Set-point | |

- SI Operates in closed loop
  - BMS asks for charge current
  - SI attempts to provide requested charging current
  - BMS shuts down inverter on fault conditions
- CAN packet sequence about 1Hz

# Questions on this section?

# Very Useful Sunny Island Functions

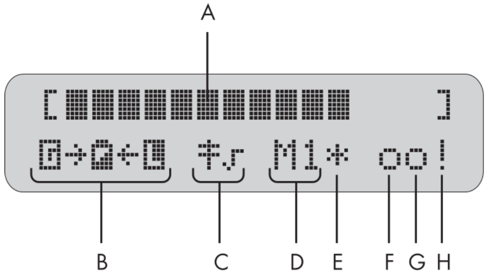
# Master Sunny Island Menu

## 7.1 Display Messages

The display of the Sunny Island has two lines, each with 16 characters.

**Meaning of the symbols**

Observe the information on the meaning of the individual symbols (see Section 10.6 "Display Messages (Overview)", page 89).

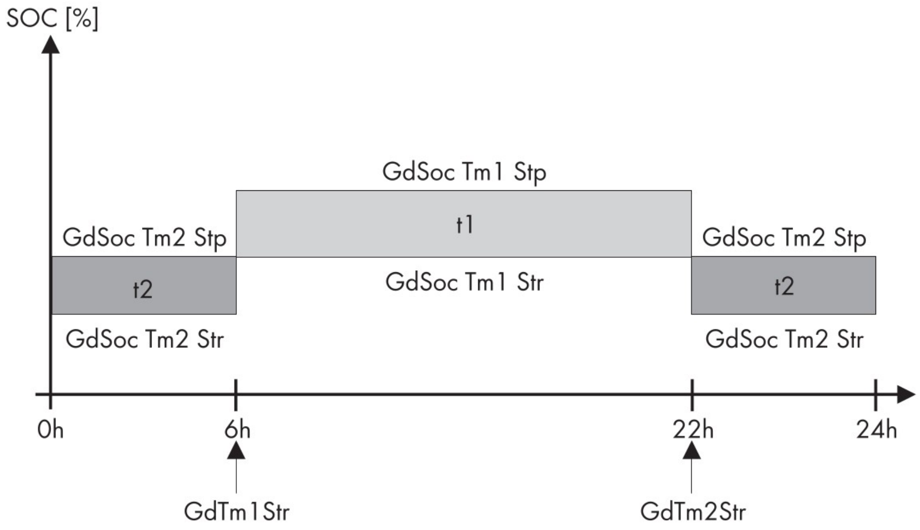



| Position | Description |
|---|---|
| A | Output power/charging power (load status) |
| B | Direction of energy flow and system status |
| C | Displays if the Sunny Island loaded parameters for grid operation or parameters for generator operation. |
| D | Device assignment |
| E | Status of the external source (asterisk, question mark or exclamation mark) |
| F | Relay 1 status |
| G | Relay 2 status |
| H | Warning message (exclamation mark) |

**Overview of the Menu Structure:**

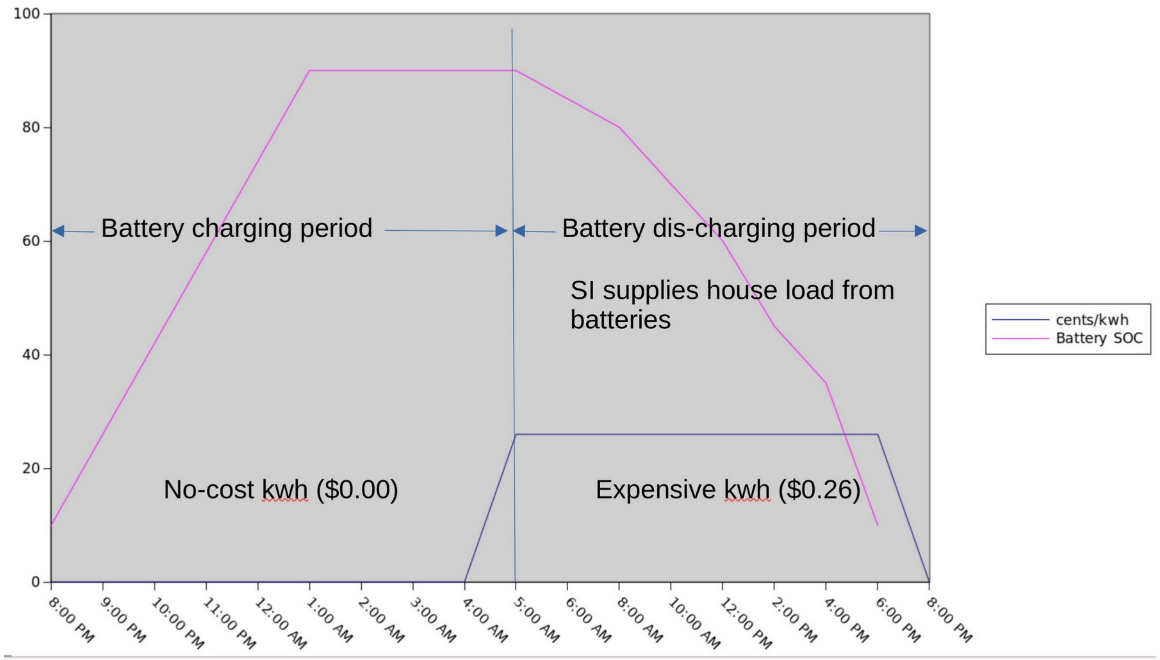
- Home Screen
- 100# Meters
  - 110# Inverter Meters
    - 111# Inverter Total Meters
    - 112# Inverter Device Meters
    - 113# Inverter Slave1 Meters
    - 114# Inverter Slave2 Meters
    - 115# Inverter Slave3 Meters
  - 120# Battery Meters
  - 130# External Meters
    - 131# Total Meters
    - 132# Grid State
    - 133# Generator State
    - 134# Device Meters
    - 135# Slave1 Meters
    - 136# Slave2 Meters
    - 137# Slave3 Meters
    - 138# CHP Meters
  - 140# Charge Controller
    - Menu item can only be selected if Sunny Island Charger is installed. The Sunny Island Charger is notUL-listed.
  - 150# Compact Meters
- 200# Settings
  - 210# Inverter Settings
  - 220# Battery Settings
    - 221# Battery Property
    - 222# Battery Charge Mode
    - 223# Battery Protection
    - 224# Battery Silent Mode
    - 225# Battery Current Sensor
    - 226# BMSMode Basic / Off
  - 230# External Settings
    - 231# Ext General
    - 232# Grid Control
    - 233# Grid Start
    - 234# Generator Control
    - 235# Generator Start
    - 236# CHP Control
    - 237# CHP Start
  - 240# Relay Settings
    - 241# Relay General
    - 242# Relay Load
    - 243# Relay Timer
    - 244# Relay Slave1
    - 245# Relay Slave2
    - 246# Relay Slave3
  - 250# System Settings
  - 280# Password Setting
- 300# Diagnosis
  - 310# Inverter Diagnosis
    - 311# System Total Diagnosis
    - 312# Inverter Device Diagnosis
    - 313# Inverter Slave1 Diagnosis
    - 314# Inverter Slave2 Diagnosis
    - 315# Inverter Slave3 Diagnosis
  - 320# Battery Diagnosis
  - 330# External Diagnosis
    - 331# Grid Diagnosis
    - 332# Generator Diagnosis
- 400# Failure/Event
  - 410# Failures Current
  - 420# Failure History
  - 430# Event History
- 500# Operation
  - 510# Operation Inverter
  - 520# Operation Battery
  - 540# Operation Generator
  - 550# Operation MMC
  - 560# Operation Grid
- 600# Direct Access
  - Select Name:
  - Select Number:

# Useful Functions
# Time of Day SOC Management



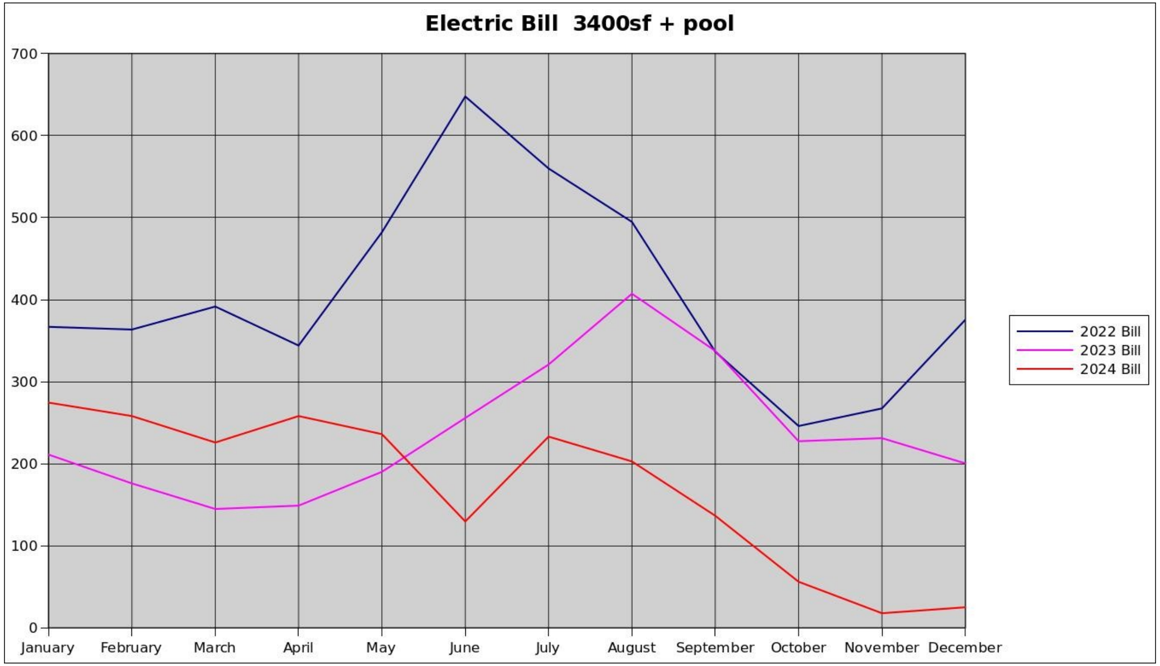

- SI SOC / Time settings

# Useful Functions
# Time-of-Use Plan Savings



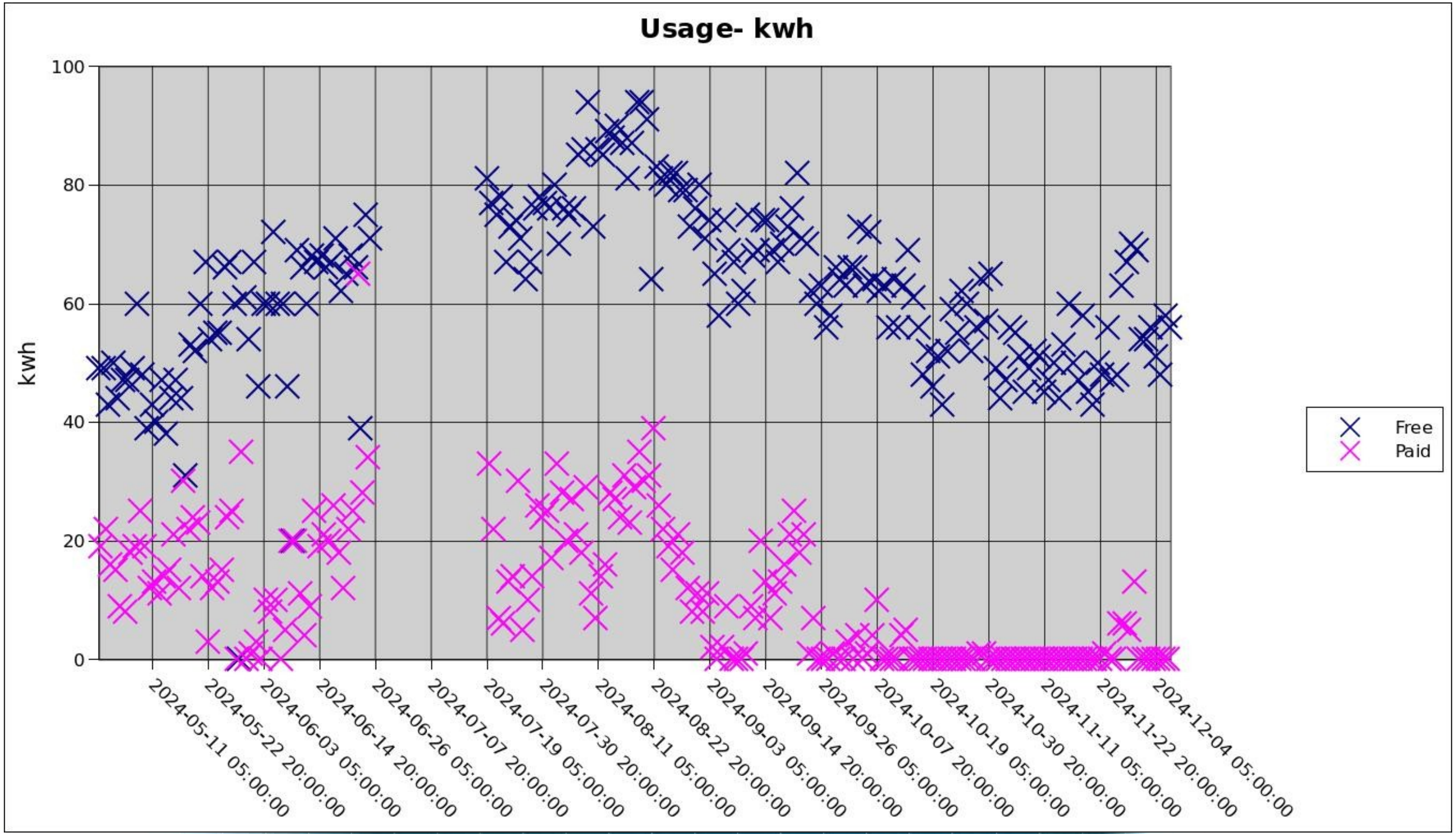

- Grid Load Time Shifting
  - Shift 35 kwh from 8am-5pm to 8pm-5am
- Charge at 9kw starting at 8pm
- Battery charged by 1am or so

# Useful Functions
# Time-of-Use Plan Savings




- Started Free Nights and Solar Days May 6 2024
- Saving at least $200/month over lowest price fixed rate plan
- July 2024 odd month due to home internet failure while in Europe
  - Had neighbor switch house to full time grid

# Useful Functions
# Daily Consumption



# Energy and power - battery

## Battery

a few seconds ago

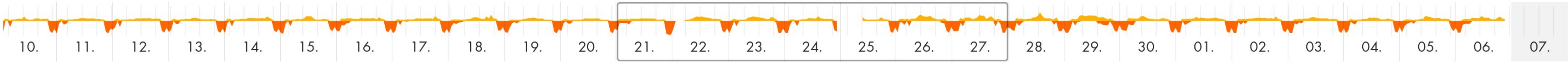
**20** %
Battery state of charge

**7,600** W
Charging power

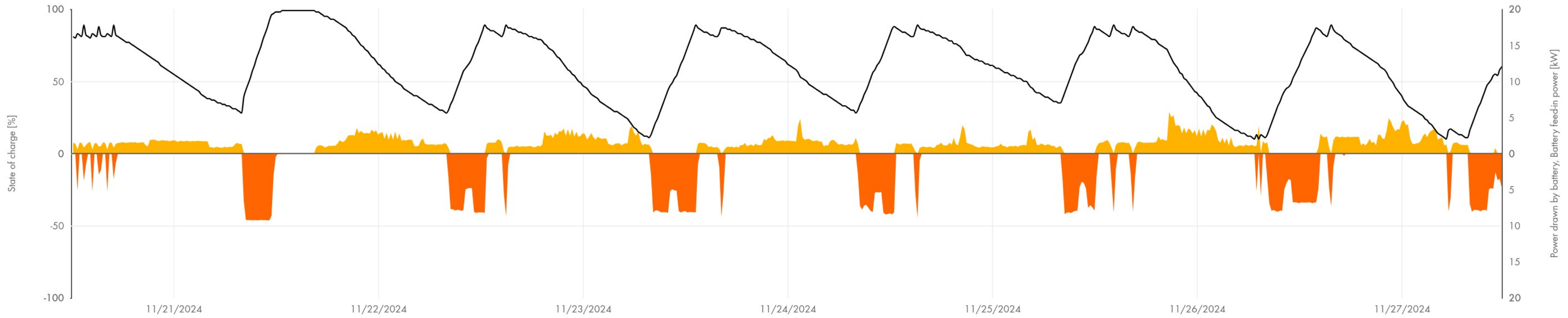
## Overview

| 24 Hours | 7 Days | 30 Days | 12 Months | Total<br>20 Months |
|---|---|---|---|---|
| 35.40 kWh Discharge | 230.50 kWh Discharge | 958.70 kWh Discharge | 7,172.80 kWh Discharge | 7,172.80 kWh Discharge |
|  |  |  |  |  |
| 40.60 kWh Charge | 260.40 kWh Charge | 1,136.80 kWh Charge | 8,740.70 kWh Charge | 8,740.70 kWh Charge |

Currently | Day | **Week** | Month | Year | Total




‹ 11/27/2024 ›



# Energy and power - battery

## Battery

a few seconds ago

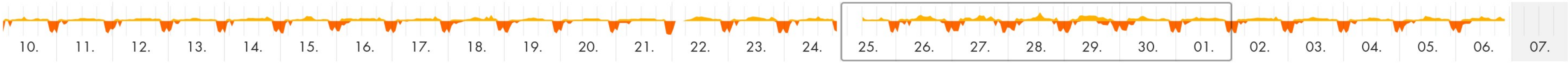
**20** %
Battery state of charge

**8,000** W
Charging power

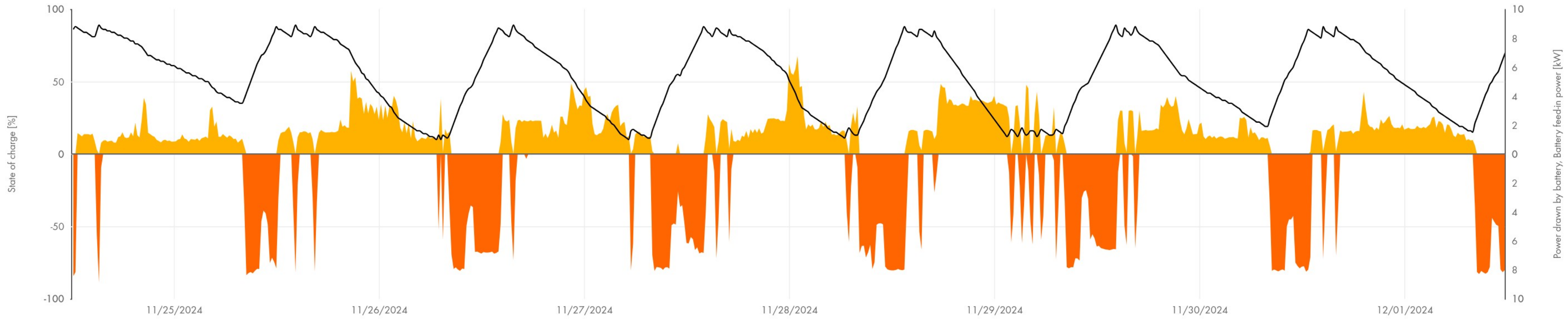
## Overview

| 24 Hours | 7 Days | 30 Days | 12 Months | Total<br>20 Months |
|---|---|---|---|---|
| 35.40 kWh<br>Discharge | 230.50 kWh<br>Discharge | 958.70 kWh<br>Discharge | 7,172.80 kWh<br>Discharge | 7,172.80 kWh<br>Discharge |
|  |  |  |  |  |
| 40.60 kWh<br>Charge | 260.40 kWh<br>Charge | 1,136.80 kWh<br>Charge | 8,740.70 kWh<br>Charge | 8,740.70 kWh<br>Charge |

Currently | Day | **Week** | Month | Year | Total




‹ 12/01/2024 ›



# Energy and power - battery

## Battery

a few seconds ago

**18** %
Battery state of charge

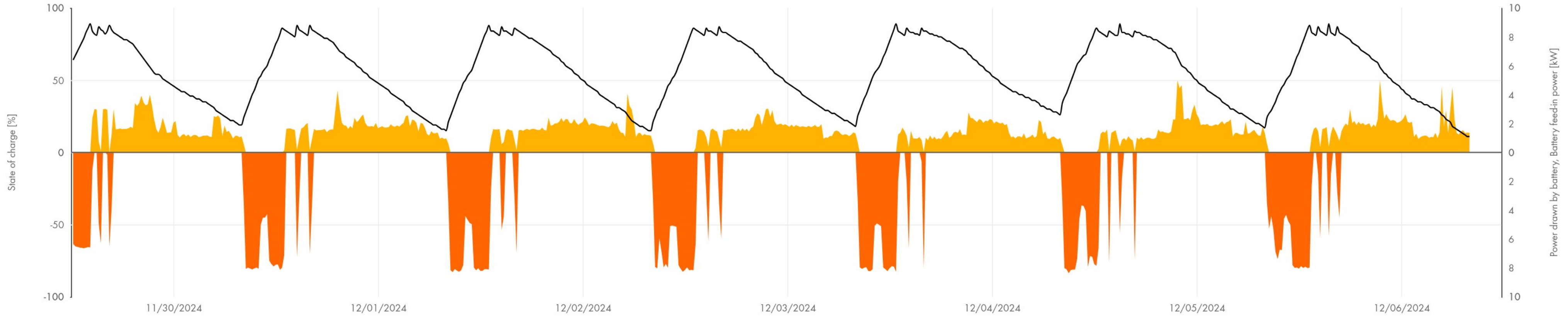
**8,500** W
Charging power

## Overview

| 24 Hours | 7 Days | 30 Days | 12 Months | Total<br>20 Months |
|---|---|---|---|---|
| 35.40 kWh<br>Discharge | 230.50 kWh<br>Discharge | 958.70 kWh<br>Discharge | 7,172.80 kWh<br>Discharge | 7,172.80 kWh<br>Discharge |
|  |  |  |  |  |
| 40.60 kWh<br>Charge | 260.40 kWh<br>Charge | 1,136.80 kWh<br>Charge | 8,740.70 kWh<br>Charge | 8,740.70 kWh<br>Charge |

Currently | Day | **Week** | Month | Year | Total


‹ 12/06/2024 ›



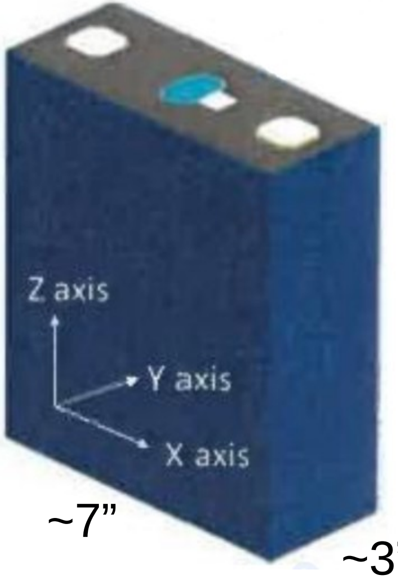
# Questions on this section?

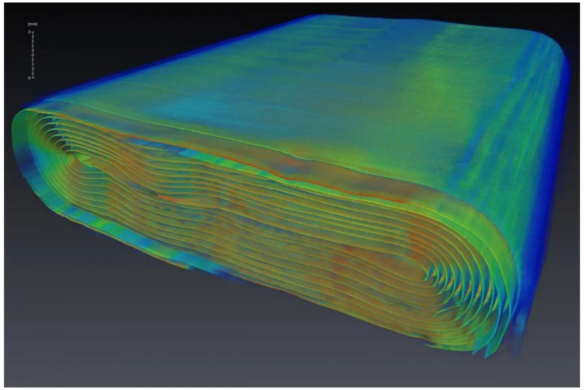
# Building LFP Modules

# Building your own LFP battery module

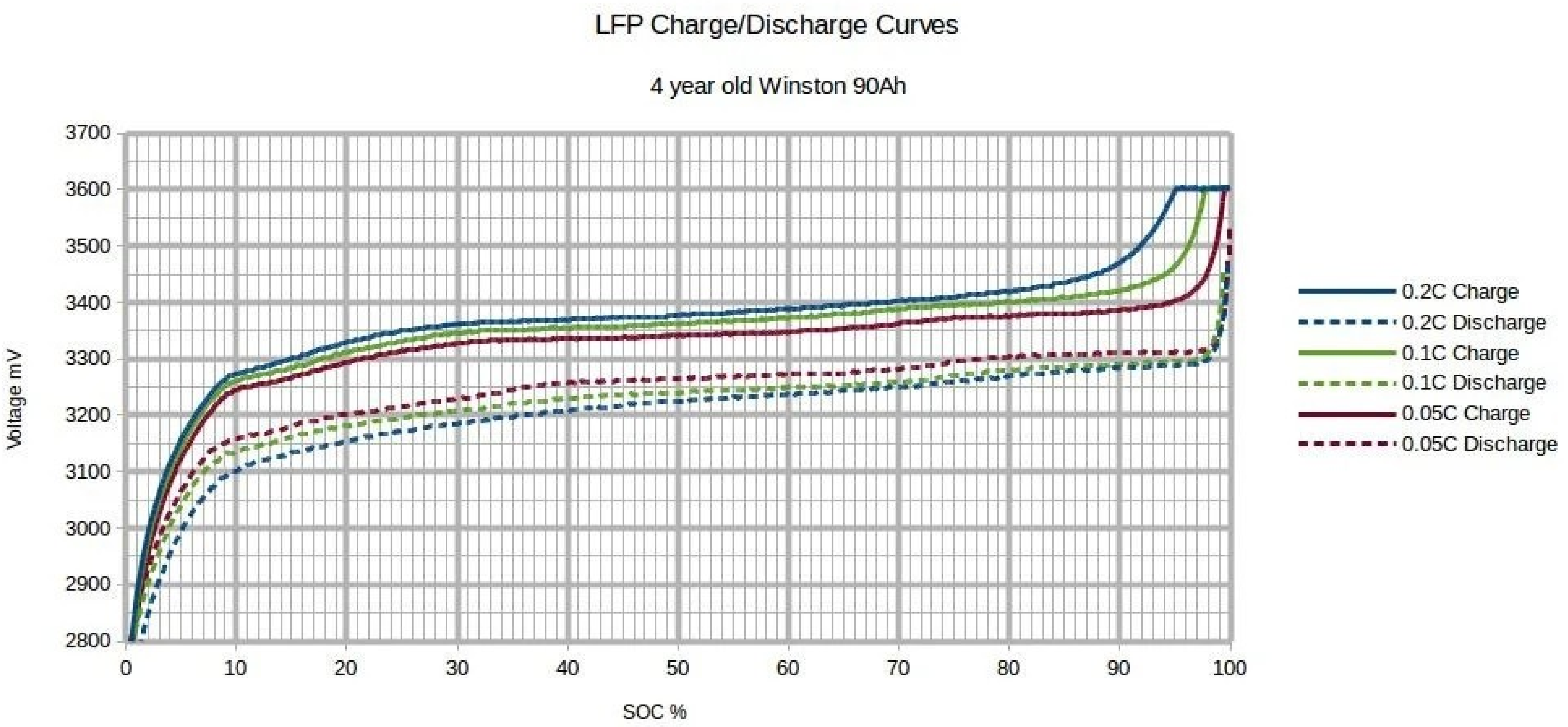
- Physical Requirements
  - Cell construction
- Safety Requirements
  - BMS options
- Series/Parallel Options
  - Designation
- Cell balancing
  - Initial + ongoing pack balancing

# Prismatic Cell Format

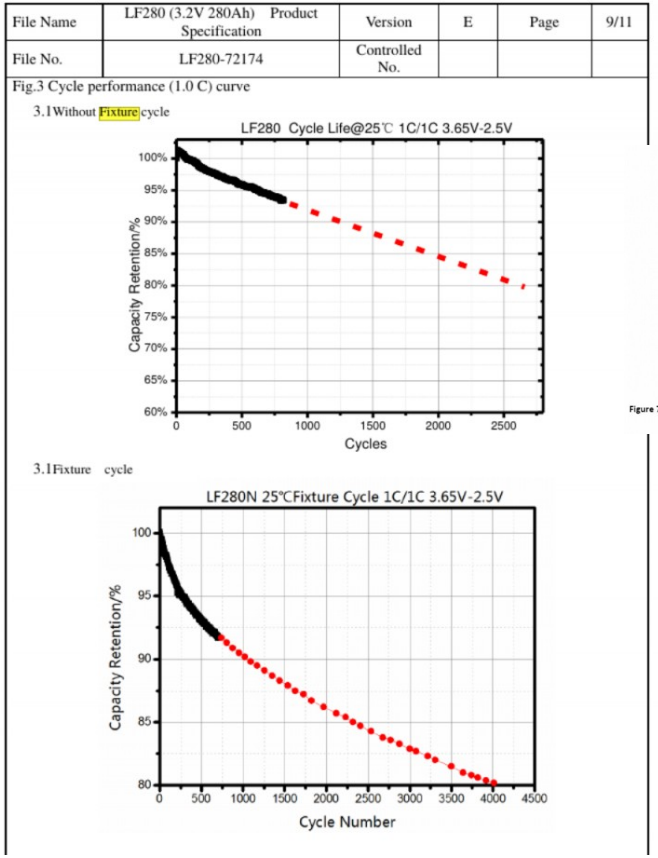


- Rectangular format – “easier packaging”
- 3.2 Vdc nominal cell voltage
- 100 to 340 amp hrs per cell
- 16 cells in series provides about 51.2Vdc
- Must have battery management system (BMS) for safety
- Aluminum cases must be isolated as they only have a thin polyfilm layer


LFP Charge/Discharge Curves
4 year old Winston 90Ah
Voltage mV
3700
3600
3500
3400
3300
3200
3100
3000
2900
2800
0
10
20
30
40
50
60
70
80
90
100
SOC %
0.2C Charge
0.2C Discharge
0.1C Charge
0.1C Discharge
0.05C Charge
0.05C Discharge

# Prismatic Cell Compression Requirements



| File Name | LF280 (3.2V 280Ah) Product Specification | Version | E | Page | 9/11 |
|---|---|---|---|---|---|
| File No. | LF280-72174 | Controlled No. | | | |

Fig.3 Cycle performance (1.0 C) curve

3.1Without Fixture cycle



3.1Fixture cycle



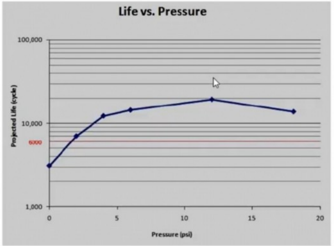
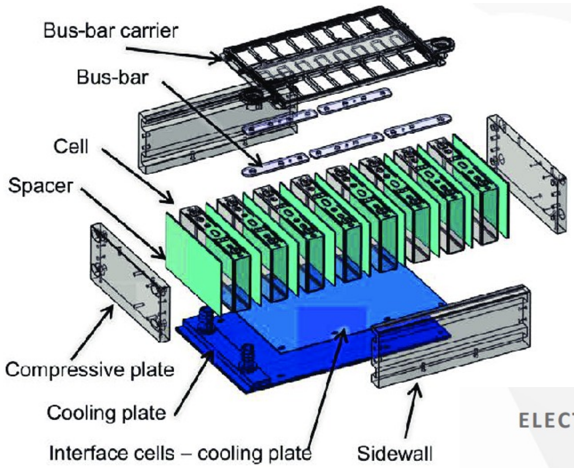


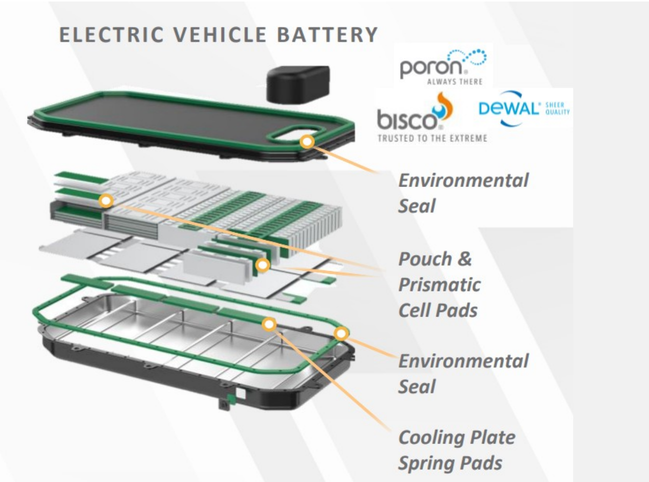


Figure 7 – Cycle life of the cell can be optimized by applying the proper pressure to the face of the cell and maintaining that throughout the life of the cell

- Longevity increases dramatically with adjustable cell compression forces
  - From 2500 to 4000 cycles
- Cells expand/contract about 1mm through chg/dischg cycles
  - Creates bus bar stress issues
- Cells expand as they age
- Cells like about 12psi on Y axis
  - Min 50kgf (2 psi)
  - Max 300kgf (12psi)
- That's about 300 kgf (660 lbs) compression over 7x8"
- And – it needs to be adaptive

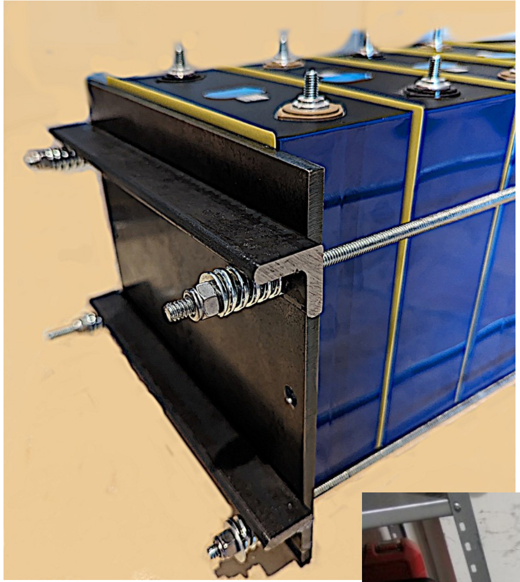
# Cell Compression Schemes




- Need to minimize cell terminal movement with SOC and age while keeping pressure about 12psi
- EV module makers using compression foam between cells
- Spring pads to maintain pressure?
- Rogers Poron EV Extend
  - e.g. 4701-43

# Home Brew Compression Schemes



- Wide variety of schemes
- Trend away from springs by using compression foam
- Or – don’t worry about cycle life

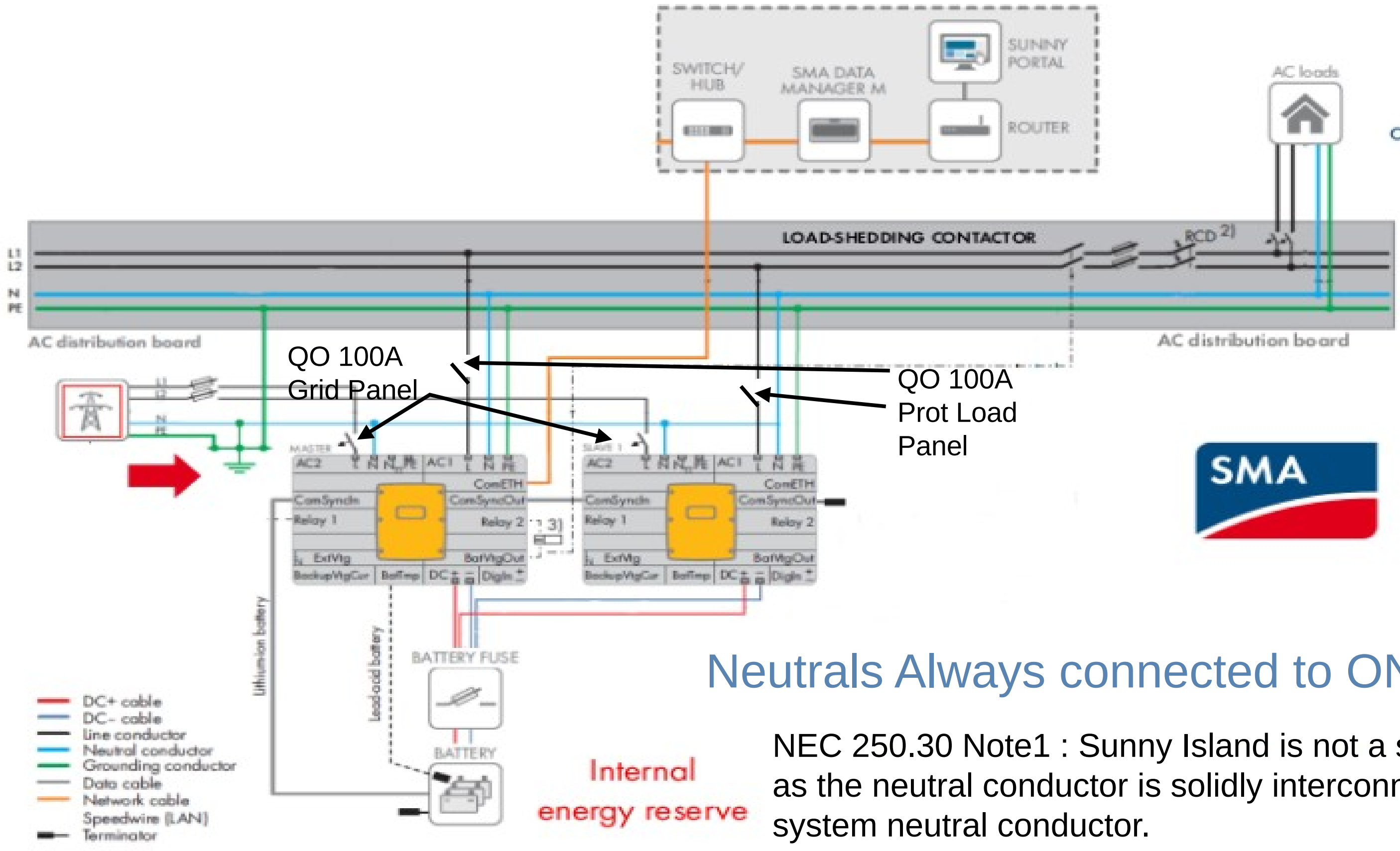

# Questions on this section?

# Useful Links

- https://www.ul.com/news/ul-9540-energy-storage-system-ess-requirements-evolving-meet-industry-and-regulatory-needs
- https://diysolarforum.com/
- https://www.solacity.com/how-to-keep-lifepo4-lithium-ion-batteries-happy/

# Misc Planning Info

# System Diagram




Load-shedding contactor highly recommended

HOM 200A Protected Load Panel

Neutrals Always connected to ONCOR Grid

NEC 250.30 Note1 : Sunny Island is not a separately derived system as the neutral conductor is solidly interconnected to the service-supplied system neutral conductor.