Engineering Design Considerations

Safety for Lithium-Ion Battery Use in Data Center Application

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April 2018

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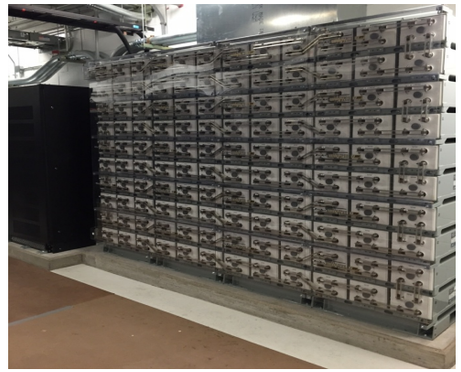
IS LITHIUM-ION BATTERY SAFE FOR DATA CENTERS?

20 year wet cells

VRLA on rack



20 year VRLA

Flywheel

VRLA

TPPL VRLA

Lithium-Ion

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LITHIUM-ION PRO VS. CON – 50 KVA + UPS

Lithium- Ion Pro - Technical

- **Lowest TCO -** – no replacement in 15 +years
  Break even is at first VRLA replacement
- **Smaller lighter footprint- about 25% of Lead**
- **Lower maintenance – 50% plus**
- **EOL typically drops 20% versus 50% time for lead acid**
- **Less temperature sensitive**
- **Totally sealed in multiple layers – no ventilation**
- **Computer managed (BMS) for status, performance and safety**
- **Order magnitude better cycle life versus VRLA**
- **Up to four times longer shelf life before recharge**
- **Becoming mainstream as Electric Cars only use Lithium**
  UPS application benefits from acceptance/volume of cars
  Bloomberg Report – Lithium will be 43% of UPS by 2025

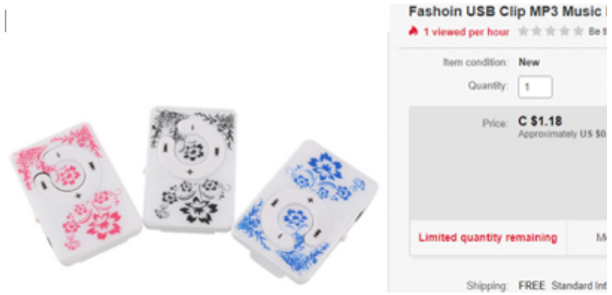
Lithium-Ion Con - Emotional

- **Higher initial cost**
- **Small installed base – new technology**
- **Only 8 years use on large UPS – 4 years in USA**
- **Only 5 UL 1973 listed models**
  Each mfg. only has one size
  Long involved process to get UL listing
  UL listing includes cell, computer and cabinet
  Can't put Lithium-Ion into existing cabinets
- **Very high capital cost to get into Lithium Mfg.**
- **Short discharges limited by Chemistry and BMS**
- **Tainted perception due to early problems**
  Boeing 787, Hoverboards, Note 7
  "Please remove all Lithium batteries your luggage"

WILL LITHIUM BATTERIES IN A UPS CATCH FIRE?

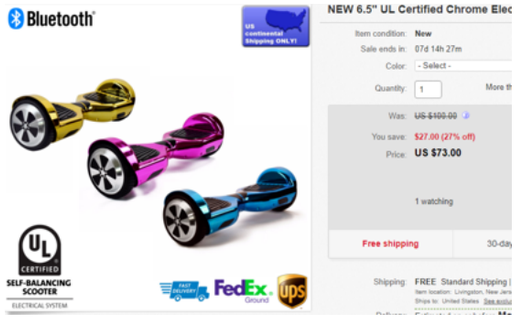
Consumer electronics batteries have numerous constraints

- Maximum run time in the smallest possible space
- Minimal space available for battery management circuitry
- Minimal space available for cooling



All prices are in USD.

Price Break	Unit Price	Extended Price
1	4.50000	4.50



Price: US $39.95

Buy It Now

Add to cart

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SAFETY: FEATURES OF LITHIUM BATTERIES USED IN UPS

	Consumer Electronics	EV & ESS Prismatic
		 UL1973 Listed
Chemistry	LCO and LFP	LFP, LMO/NMC and LTO
Customer Requirements	Higher energy density = Thin thickness	Safest design considering car accidents
R&D period	**3 – 6 months** (Short R&D period to meet customers' schedule)	**2 – 3 years** (Enough verification period)
Safety device	Minimal Battery Management System	Extensive BMS – Electrical Safety Device OSD and Fuse – Physical Safety Device

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UPS LITHIUM BATTERY EVOLVED FROM ELECTRIC CARS

LiiON/Valence – USA & China

- First UL1973 listingfor UPS in 2014 based upon **Valence** electric bus battery of parallel 2.5Ah cells – LithiumWerk purchased Valence March 2018

Samsung – Korea

- Manufactures large 67 Ah Prismatic cells based upon **BMW i8** and **i3** battery, 44 UPS installations in Korea since 2011
- **UL1973 listing July 2016** with first 3.3mW installation on NXL Jan 2017, over 400 cabinets by Vertiv with additional ones by APC and Eaton

LG Chem - Korea

- Automotive supplier to **GM** , Vertiv 30 mW site UPS in Korea – **UL1973 October 2017** – looking at UPS market in US
- **NEC** – offers ESS cabinets built with LG Chem modules – exploring UPS market

Toshiba - Japan

- Offering UPS 20 Ah Lithium-Ion battery based upon ESS and **Honda** battery – **UL1973 Listed**

Saft – Europe & USA

- High technology Military/Industrial product Including **Ferrari F1 race** cars–expect **UL1973 April 2018** – exploring UPS market

A123 – US & China

- **Mercedes, BMW, Porsche, Volvo hybrid** battery use A123's 35 Ah and 50 Ah Prismatic cell - Exploring UPS market

Enersys - China

- Announced will have a Lithium UPS UL1973 battery by end of 2019

NO VENTILATION NEEDED

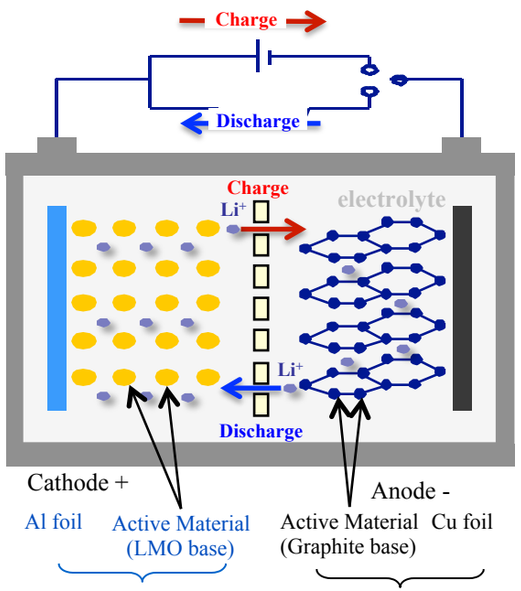
- LIB is based on Li-ion transfer from negative to positive electrodes
- No chemical reactions between electrolyte and electrodes during charging/discharging
- Totally sealed – vents only on destruction (Thermal Runaway)

Lithium Ion Battery

Reaction :

$$LiMn_2O_4 + C_6 \leftrightarrow Li_{1-x}Mn_2O_4 + Li_xC_6$$

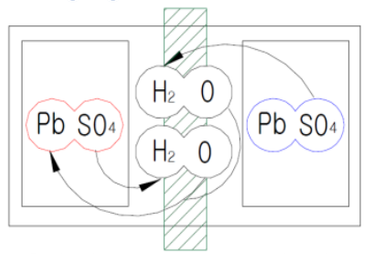
No Gas emission during normal charge/ discharge



Anode - intercalation graphite
Cathode - Lithiated Manganese Oxide (LMO)
Electrolyte - Lithium hexafluorophosphate, organic carbonates / No gassing on charge/discharge

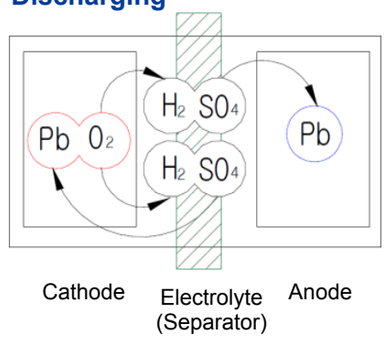
Lead Acid

Charging



$$2PbSO_4 + 2H_2O \rightarrow Pb + PbO_2 + 2SO_4^{2-} + 4H^+$$

Discharging



$$Pb + PbO_2 + 2SO_4^{2-} + 4H^+ \rightarrow 2PbSO_4 + 2H_2O$$

Gas emission during normal charge/discharge -Sulfurous acid gas, Hydrogen gas, Oxygen -VRLA combines hydrogen and oxygen to produce heat

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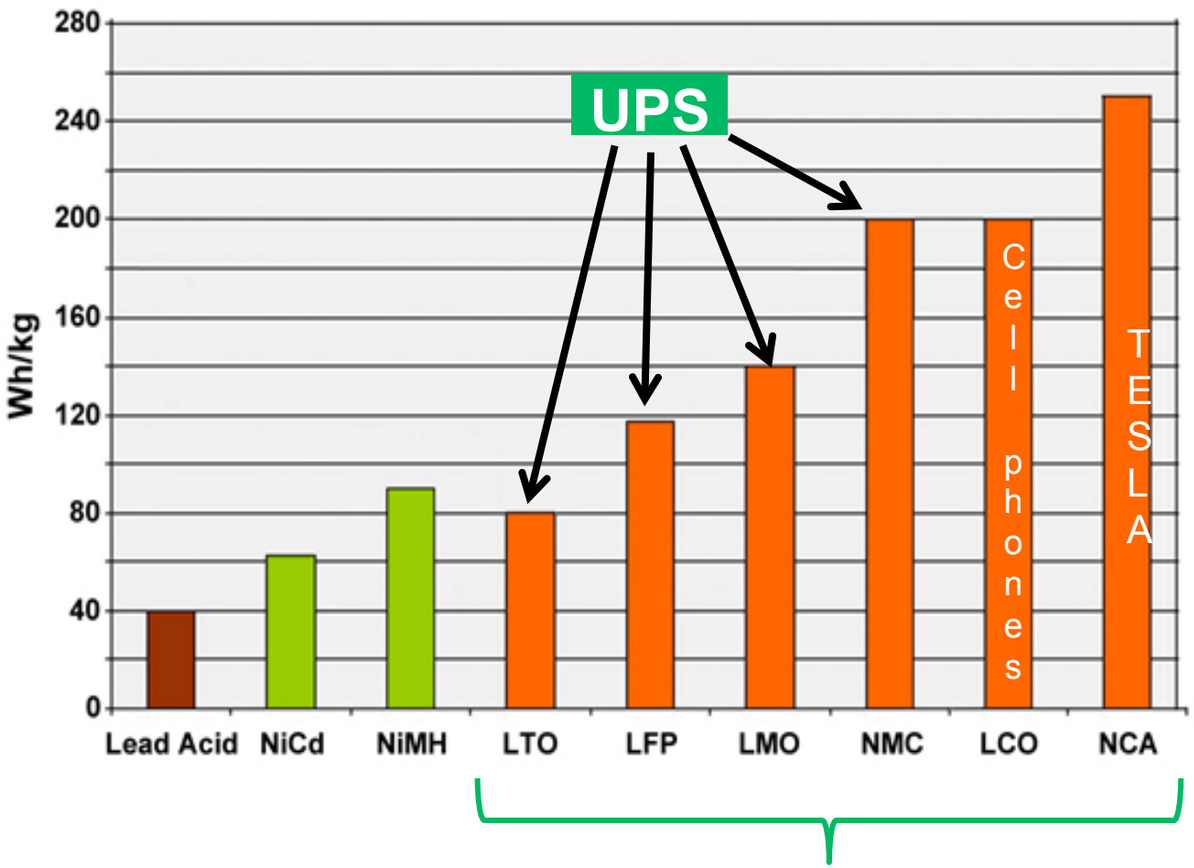
DIFFERENT LITHIUM ION CHEMISTRIES

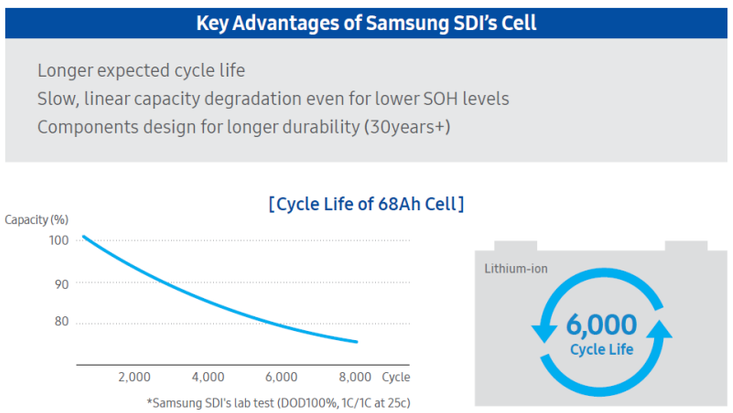


- Handheld electronics and laptop mostly use Lithium cobalt oxide (LCO), which offers high energy density but presents safety risks, especially when damaged.
- Lithium iron phosphate (LFP), Lithium manganese oxide battery (LMO)
- Lithium nickel manganese cobalt oxide (NMC) offer lower energy density, short run-times but longer life and inherent safety
- Lithium titanat **(LTO)** provides quickest recharge and highest discharger currents but lowest energy storage at highest cost
- Source: Wikipedia

SAFETY: PICK THE RIGHT CHEMISTRY FOR APPLICATION

Main Li ion Variant	Principal use	Typical 100% DOD Cycle Life	Shortest Discharge	Potential (Voltage)	Start of Thermal Run Away	Relative Price
LCO	Cell phones-laptops	600	60 min.	3.6	170˚C	100%
NCA	Tesla	1300	30 min.	3.6	180˚C	150%
LMO	Elec. Car - UPS	1200	10 min.	3.8	255˚C	125%
NMC	Elec. Cars - UPS	1300	6 min	3.7	215˚C	150%
LFP	Power tools-Hybrid-UPS	3000	6 min.	3.2	270˚C	135%
LTO	Grid storage and hybrid cars	12,000	6 min	2.5	Not Susceptible	300%

Long Cycle Life



Typical VRLA

TABLE B - WARRANTED CYCLE LIFE

Discharge Rate	Discharge** Duration	Maximum Cycle Life HX
30 min.	30 min.	100
15 min.	15 min.	120
10 min.	10 min.	140
5 min.	5 min.	180

**Discharge cycles are based on an end voltage of 1.67 Vpc.

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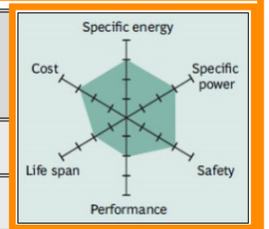
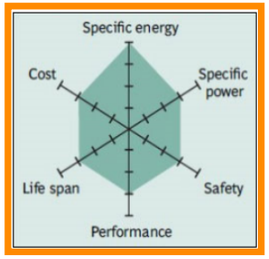
LITHIUM MANGANESE OXIDE / LITHIUM NICKEL COBALT MANGANESE OXIDE COMBINATION (LMO/NMC)

- LMO has good short term power application
- NMC has good overall performance and excels on specific energy
- LMO/NMC is a blend of manganese and cobalt **optimizes advantages** of both chemistries
- This combination brings out the best in each system and the LMO/NMC is chosen for pure electric vehicles, such as the**, Nissan Leaf, Chevy Bolt and BMW i8 & i3**.

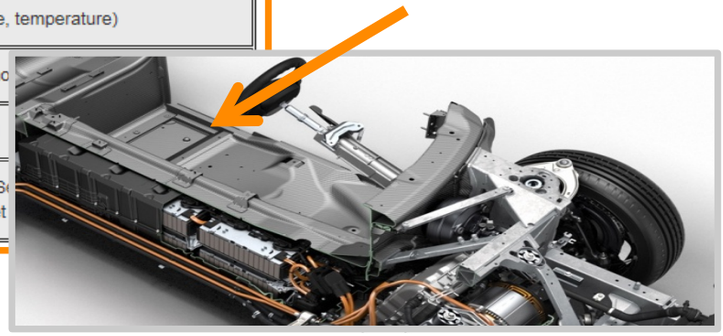
Lithium Manganese Oxide: $LiMn_2O_4$ cathode. graphite anode Short form: LMO or Li-manganese (spinel structure) 1996	
Voltage, nominal	3.70V (some may be rated 3.80V)
Specific energy (capacity)	100–150Wh/kg
Charge (C-rate)	0.7–1C typical, 3C maximum, charges to 4.20V (most cells)
Discharge (C-rate)	1C; 10C possible with some cells, 30C pulse (5s), 2.50V cut-off
Cycle life	300–700 (related to depth of discharge, temperature)
Thermal runaway	250°C (482°F) typical. High charge promotes thermal runaway
Applications	Power tools, medical devices, electric powertrains
Comments	High power but less capacity; safer than Li-cobalt; commonly mixed with NMC to improve performance.



Lithium Nickel Manganese Cobalt Oxide: $LiNiMnCoO_2$. cathode, graphite anode Since 2008 Short form: NMC (NCM, CMN, CNM, MNC, MCN similar with different metal combinations)	
Voltage, nominal	3.60V, 3.70V
Specific energy (capacity)	150–220Wh/kg
Charge (C-rate)	0.7–1C, charges to 4.20V, some go to 4.30V; 3h charge typical. Charge current above 1C shortens battery life.
Discharge (C-rate)	1C; 2C possible on some cells; 2.50V cut-off
Cycle life	1000–2000 (related to depth of discharge, temperature)
Thermal runaway	210°C (410°F) typical. High charge promo
Applications	E-bikes, medical devices, EVs, industrial
Comments	Provides high capacity and high power. S Favorite chemistry for many uses; market

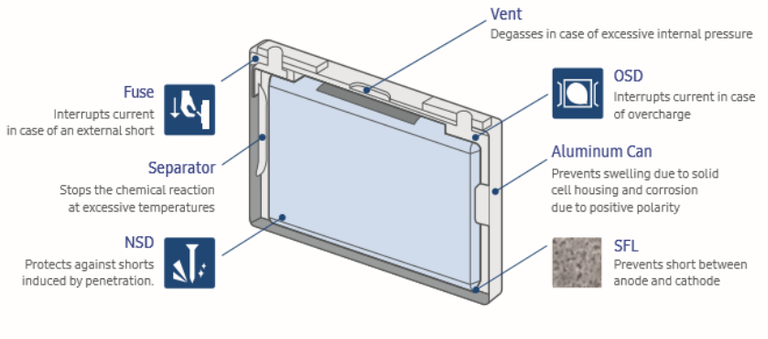


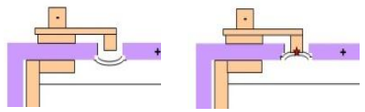
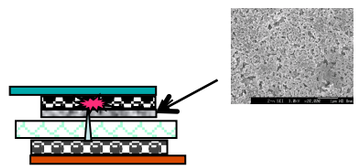
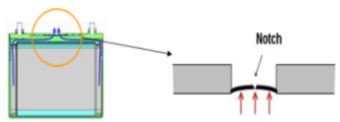
Battery is next to driver in i8



EVOLVED FROM ORIGINAL SAMSUNG 60 AH BMW CELL

Multi-layered protection at the cell level resulting in best in class safety.



Item		Function description
OSD (Overcharge Safety Device)		to cut overcharge current into electrode by activation of OSD (cut at 4kgf of Internal Pressure)
Fuse		to cut abnormal current flow
SFL (Safety Functional Layer)		to maintain electronic isolation by additional heat resistant ceramic layer on Anode
Gas Vent		to vent generated gas in case of emergency (venting at 7kgf of Internal Pressure) **2/3 CO2 and 1/3 CO, H2 and CH4**

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LITHIUM IRON PHOSPHATE (LFP)

- Excellent safety
- Long service life span and higher cycle life
- Lower voltage than other lithium battery chemistries
- Higher self-discharge than other lithium battery chemistries
- Best chemistry for **high power, short discharge** application
- Chosen by **Porsche, Mercedes, Volvo and BMW for hybrid** electric cars and F1 and LeMans race cars

LG Chem

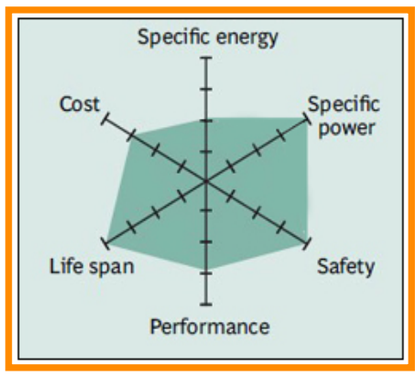
NEC NEC ENERGY SOLUTIONS

valence

A123 SYSTEMS

Lithium Iron Phosphate: $LiFePO_4$ cathode, graphite anode Short form: LFP or Li-phosphate Since 1996	
Voltage, nominal	3.20V, 3.30V
Specific energy (capacity)	90–120Wh/kg
Charge (C-rate)	1C typical, charges to 3.65V; 3h charge time typical
Discharge (C-rate)	1C, 25C on some cells; 40A pulse (2s); 2.50V cut-off (lower that 2V causes damage)
Cycle life	1000–2000 (related to depth of discharge, temperature)
Thermal runaway	270°C (518°F) Very safe battery even if fully charged
Applications	Portable and stationary needing high load currents and endurance
Comments	Very flat voltage discharge curve but low capacity. One of safest Li-Ions. Used for special markets. Elevated self-discharge.

2017 F1 World Champion



2017 24 hour LeMans Winner

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RECYCLING – WILL EVOLVE FROM ELECTRIC VEHICLE

- During 10 year warranty period failed cells are returned to Vertiv and the cells manufacturer

Industry Consultant

“Lithium-ion battery recycling market is estimated at USD 1.78 billion in 2017 and is projected to reach USD 23.72 billion by 2030”,

“The automotive segment is expected to grow at the highest CAGR from 2017 to 2030”

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I3 battery recycled as home back-up

BRIEFS

BMW hit 2017 100,000 electrified-vehicle goal, plans 300,000 more by 2019

The plan was for the BMW Group to sell 100,000 BMW i and iPerformance models worldwide in 2017. On December 18, 2017—rather in the nick of time—Harald Krüger, chairman of the BMW AG Board of Management announced the completion of that goal. He made it official by symbolically turning BMW's "four-cylinder" headquarters building in Munich into four big blue batteries.

"We deliver on our promises," said Krüger as he lit up the building. "This 99-meter-high signal is lighting the way into the era of electromobility. Selling 100,000 electrified cars in one year is an important milestone, but this is just the beginning for us. Since the introduction of the BMW i3 in 2013, we've delivered over 200,000 electrified cars to our customers, and by 2025, we will offer 25 electrified models. Our early focus on electromobility has made this and somewhat autonomous BMW iNext car, BMW's electrified powertrains will be scalable to the extent that any BMW model in any plant in the world can be built as a conventionally powered vehicle or an electric one. Toward that end, BMW has trademarked a number of names that include the letter "i," from the i1 to i9 and the iX1 to iX9.

According to the German weekly paper WirtschaftsWoche, Krüger now has a new goal: 500,000 total electrified BMW Group deliveries by the end of 2019. To be clear, the new goal is not to sell a total of 500,000 more electrified BMWs and Minis in two years, but to sell about 300,000—enough to bring the total BMW Group electrified vehicle score up to 500,000 by December 2019.

Put another way, BMW needs to average 150,000 electrified vehicles sold in both 2018 and 2019.

208 Toyota battery recycled in Solar backup for Yellowstone Nation Park

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UL CERTIFICATION – 18 MONTHS ON AVERAGE

Test	Description	Criteria
Short Circuit (RT)	Short of <100mOhms	Max temp <150C, no explosion or fire
Short Circuit (55C	Short of <100mOhms, 55C	Max temp <150C, no explosion or fire
Abnormal Charge	Charge with 3x maximum specified charge current to maximum target charge V (4.5V)	No fire or explosion
Crush	Cell crushed between flat plates up to force of 3000lb (13kN)	No fire or explosion
Impact	15.8mmbar dropped from height of 61cm onto longitudinal axis, with 9.1kg mass	No fire or explosion
Shock	125 to 175g magnitude shock in each of 3 perpendicular directions	No leak, fire or explosion
Vibration	10 to 55Hz vibration at 1Hz/min increase and back down across each 3 perpendicular directions	No leak, fire or explosion
Heating	Heat at 5C/min to 130C for 10 minutes	No fire or explosion
Temp Cycling	70C to -40C cycling –4 hours at each temperature, repeat 9 times	< 0.1% mass loss
Low Pressure	6 hours at 11kPa (1.68 psi)	No leak, vent, fire or explosion
Projectile	Cell placed onscreen above burner according to UL specified setup until explosion or burned out	Cannot penetrate mesh screen

UL 1642
(Cell Safety)

UL 1973
(Cabinet/System)

UL 1973	Configuration	States
OVERCHARGE TEST	System	In Compliance
SHORT CIRCUIT TEST-PART A	System	In Compliance
SHORT CIRCUIT TEST-PART B	System	In Compliance
OVERDISCHARGE PROTECTION	System	In Compliance
TEMPERATURE AND OPERATING LIMITS CHECK TEST	System	In Compliance
IMBALANCED CHARGING TEST	System	In Compliance
STEADY FORCE TEST	Module	In Compliance
DROP IMPACT TEST	Module	In Compliance
WALL MOUNT FIXTURE/HANDLE TEST	Module	In Compliance
MOLD STRESS TEST	Module	In Compliance
INTERNAL FIRE EXPOSURE TEST	Module	In Compliance
DIELECTRIC WITHSTAND TEST	System	In Compliance
WORKING VOLTAGE MEASUREMENT	System	In Compliance
INPUT TEST	System	In Compliance
CONTINUITY TEST	System	In Compliance
FINAL CYCLING AND DIELECTRIC TEST	System	In Compliance
FINAL REPORT AND DOCUMENATION	Module and System	Complete

Requirements)	Configuration	States
ENVIRONMENTAL STRESS OF TEMPERATURE	LMMS PCBA and L24F	In Compliance
THERMAL CYCLING TEST	LMMS PCBA and L24F	In Compliance
VOLTAGE DIPS AND INTERRUPTIONS IN THE POWER SUPPLY NETWORK -AC Supply only	LMMS PCBA and L24F	In Compliance
VOLTAGE VARIATION TEST	LMMS PCBA and L24F	In Compliance
SURGE IMMUNITY TEST	LMMS PCBA and Char	In Compliance
ELECTRICAL FAST TRANSIENT/BURST IMMUNITY TEST	LMMS PCBA and Char	In Compliance
RING WAVE TEST (UL)	LMMS PCBA and Char	In Compliance
ELECTROSTATIC DISCHARGE TEST	LMMS PCBA and L24F	In Compliance
ELECTROMAGNETIC FIELD IMMUNITY - IMMUNITY TO CONDUCTED DISTURBANCES	LMMS PCBA and L24F	In Compliance
IMMUNITY TO RADIATED ELECTROMAGNETIC FIELDS	LMMS PCBA and L24F	In Compliance
TEST OF INFLUENCE OF SUPPLY FREQUENCY GENERATIONS	LMMS PCBA and L24F	In Compliance
POWER FREQUENCY MAGNETIC FIELD IMMUNITY TEST	LMMS PCBA and L24F	In Compliance
SINGLE FAULT CONDITIONS	LMMS PCBA and L24F	In Compliance
FINAL REPORT AND DOCUMENATION	LMMS and Module	Complete

Requirements)	Configuration	States
REVIEW AND AUDIT OF FIRMWARE AND DESIGN/PROCESS DOCUMENTATION	LMMS PCBA and L24F	In Compliance
INTERNAL TEST REPORTS	LMMS PCBA and L24F	Complete
UNIQUE IDENTIFIERS	LMMS PCBA and L24F	In Compliance

™

2018 NFPA FIRE CODE 1– LITHIUM-ION SECTION 52.3 HIGHLIGHTS

Prescription for how to safely deploy Lithium-Ion Battery in a building

- The Consulting Engineer and AHJ have the responsibility to determine compliance not Vertiv
- Applies to LIB installation in that exceed 20 KWh
  - Maximum array (cabinet) size is 50 KWh with exceptions for Listed cabinets (52.3.2.3.2 & 52.3.2.3.5)

Requires UL1973 Listing (52.3.2.5)

- Include an approved BMS (52.3.2.6.1) with thermal Runaway Management (52.3.2.10 & 52.3.2.11.1)
- BMS to send alarm notification (52.3.2.6.1) on hazardous conditions
- Prepackaged cabinets shall be installed in accordance with their Listing and Manufacturers Instructions (52.3.2.5.2)

Location Restrictions

- Not above 75 feet from fire engine access – not below 30 feet of fire escape level (52.3.2.1.2.1) unless AHJ allows
- The UPS and LIB may be installed in the same room (52.3.2.1.3)
- Rooms exceeding 600 KWh High Hazard classifications apply unless exempted by the AHJ (52.3.2.2.2)
  - 18 Samsung 128s cabinets
- Special signage such as “Authorized Personnel Only” may be required (52.3.2.6.5.2)
- Rooms may require protection by an automatic sprinkler system (52.3.2.7.1)
- Smoke detection may be required (52.3.2.7.2)
- LIB which don’t produce gas on charging may not require ventilation (52.3.2.8)

20 KWh
480vdc =40AH , 200 watt
Samsung 128s = 32.6 kWH

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FIRE SUPPRESSION

- For UPS Cells the Lithium is in a non-flammable salt
- The electrolyte (Ethyl Methyl carbonate and related compounds) is flammable
- BMS disconnect the battery but 540v would remain in the cabinet
  - For personnel safety a gaseous fire suppressant may be desired due to the electrical nature of the fire
    - Clean agent such as FM-200, NOVEC1230 or HFC23 should be used
    - Specialty Lithium fire extinguishers are available if required by local codes – color coded Yellow
- Check with local fire codes to determine what is required locally

~ 2 min (120 s) **~ 2.5 min (150 s)** **> 6 min (360 s)**

Water based sprinkler, centered over the main array, operated at 1 min 30 s (90 s) and suppressed the **electrolyte** (ethyl methyl carbonate and related compounds) fire in boxed LFP cells

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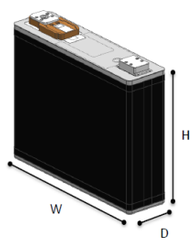
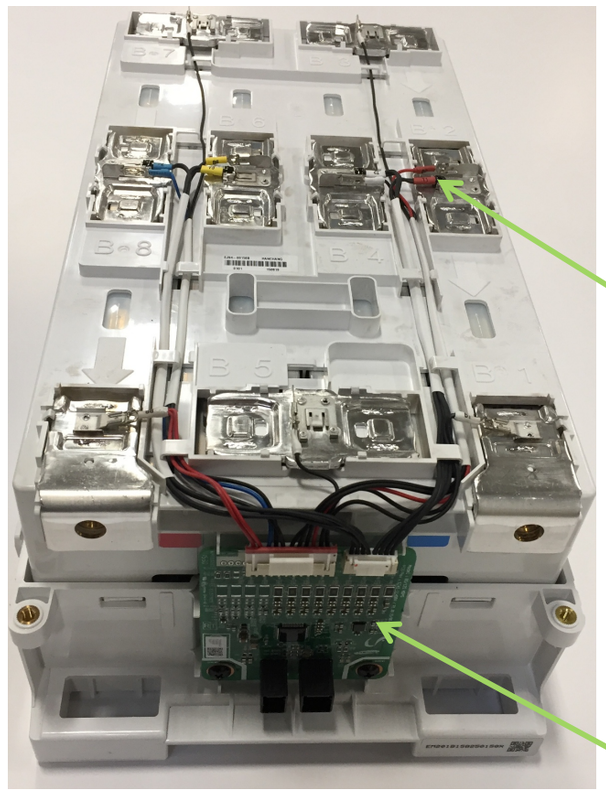
CELL, MODULE & CABINET DIMENSIONS

■ LMO based high reliability battery cell has used for 10min. backup battery system.

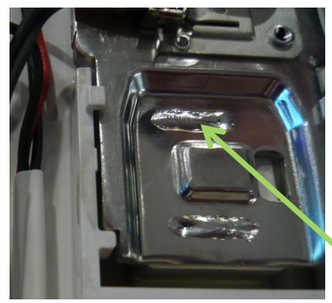
Item		Unit	Specification
CAN Type LIB 	Dimension (bare cell)	mm	173.9 x 45.6 x 125.7
	Weight	kg	1.880
	Nominal Capacity	Ah	67
	Nominal Voltage	V	3.80
	Nominal Energy	Wh	254
	Upper Limit Voltage	V	4.20
	Lower Limit Voltage	V	2.70
	Cell Connection Method	-	Laser welding

Item		Unit	Specification
	Dimension (W*H*D)	mm	216 x 163 x 414
	Configuration	-	8S1P
	Nominal Capacity	Ah	67
	Nominal Energy	kWh	2.036
	Nominal Voltage	V	30.4
	Operation Voltage	V	24.0 ~ 33.6
	Weight	kg	17
	BMS	-	Module BMS 1EA
	Cell Connection Method	-	Laser welding

DC Fuse: 500A
MCCB: 600A CB
NFPA Fire Code rating: 32.6 KWh

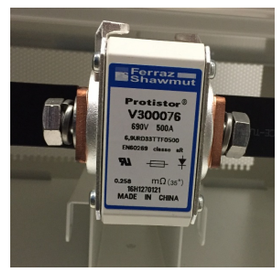


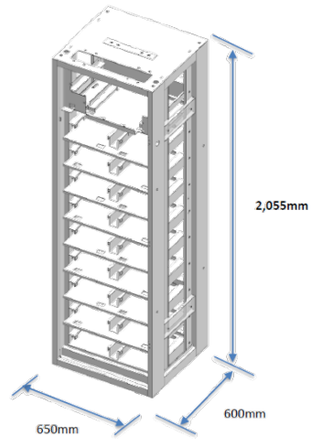
Cell level temperature and voltage



Laser welded internal cell connections

Module BMS





[Single Rack Size]

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BMS ARCHITECTURE

■ BMS Configuration

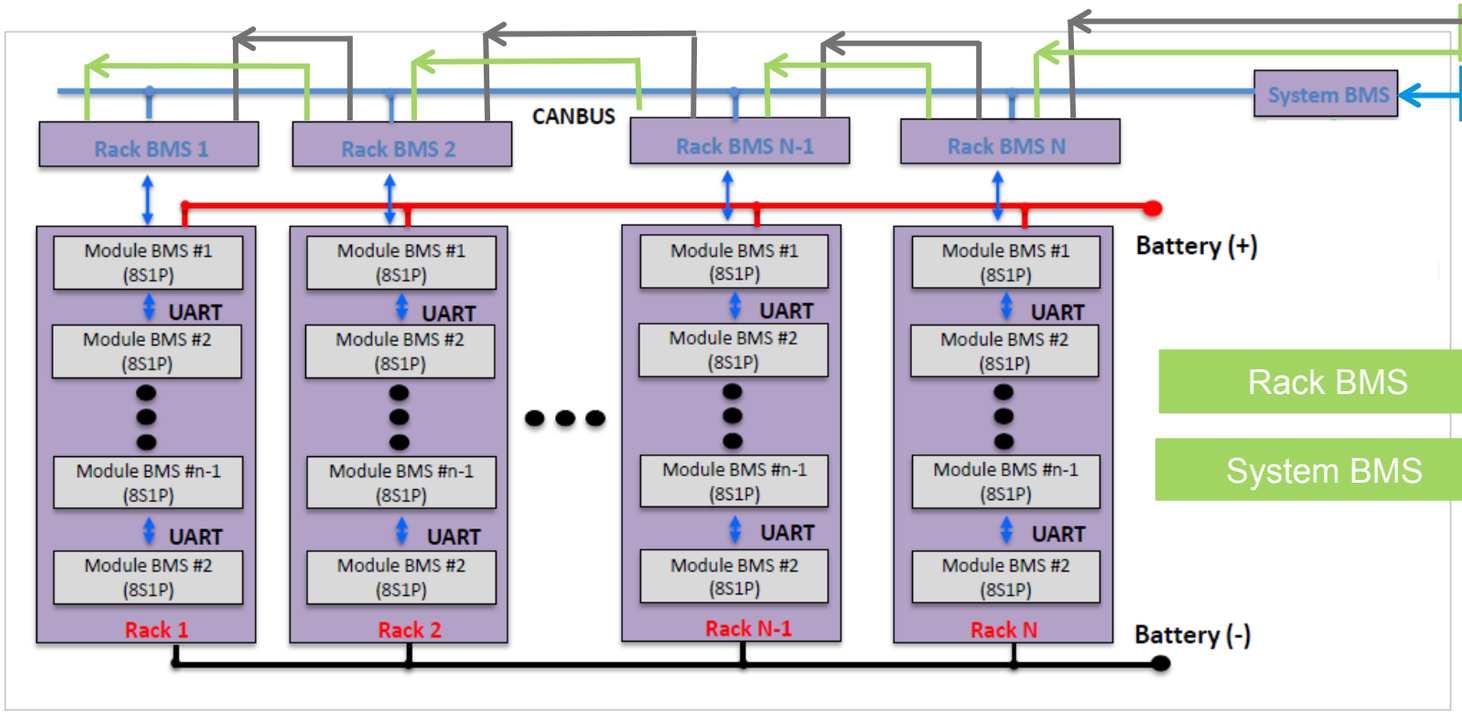
- 3 Step BMS Design : Module BMS → Rack BMS → System BMS
- Module BMS : Cell Voltage and Temperature Measure, Communication to Rack BMS
- Rack BMS : Rack Voltage and Current Measure, SOC and SOH Calculation, Protection Control, Communication to System BMS

Dual A&B power feeds Daisy chain or
home run from 480v lighting panel – max 12 cabinets

480v A & B

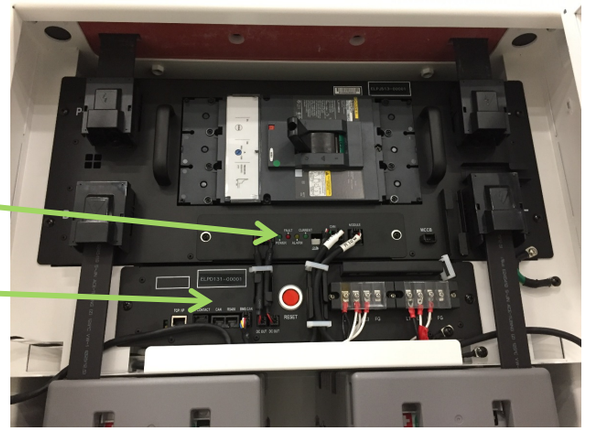
UPS Dual 7.5a

BIB & ModBUS



Rack BMS

System BMS



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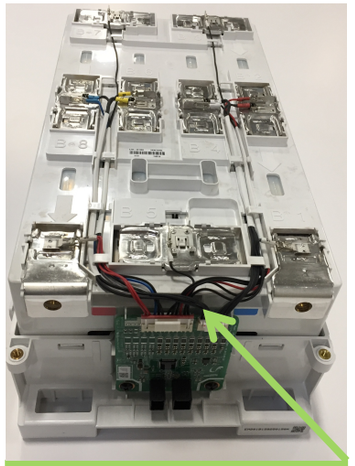
BMS MONITORING MATRIX

Function		System BMS	Rack BMS	Module BMS
Measurement	Rack Voltage / Current	-	○	-
	Cell Voltage / Temp	-	-	○
Calculation	SOC Estimation	-	○	-
	SOH Estimation	-	○	-
Control	Switching Control	-	○	-
	Cell Balancing	-	○	○
Communication	UART	-	○	○
	CAN	○	○	-
	RS-485 or MODbus-TCP/IP	○	-	-
	Dry Contact	○	-	-

SIGNAL NAME	
MCCB COMM	Customer
ALL MCCBs OPEN	Customer
MCCB CLOSED	Customer
TRIP BCB INPUT	Open Rack CB
TRIP BCB COM	Open Rack CB
MINOR ALARM NO	UPS Maintenance
MINOR ALARM NC	UPS Maintenance
MINOR ALARM COM	UPS Maintenance
MAJOR ALARM NO	UPS Critical
MAJOR ALARM NC	UPS Critical
MAJOR ALARM COM	UPS Critical

Dry Contact



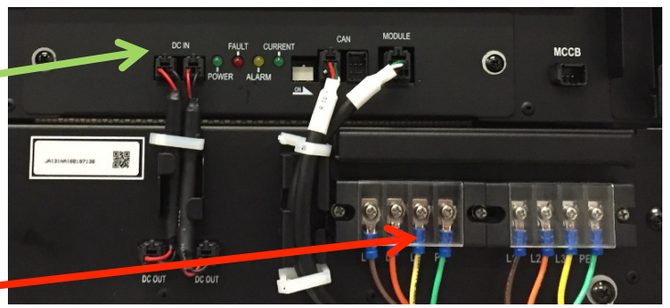
Module BMS

Rack BMS
Shutdown on failure

System BMS

Redundant
480V input

Dry Contact



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PROTECTION MAP

- Cell Level protection map

	Level	Condition	MCCB
Over Voltage Protection	Major	Max cell ≥ 4.28V, 5sec	Off
Under Voltage Protection	Major	Min cell ≤ 2.5V, 3sec	Off
Over Temperature Protection	Major	Max Temp ≥ 75℃, 3 sec	Off
Under Temperature Protection	Minor	Min Temperature ≤ 0℃, 3sec	On

4.2v = 538 vdc float
4.28v = 547 vdc
4.8v = 614V-thermal runaway

- Rack Level protection map

	Level	Condition	MCCB
Over Voltage Protection	Major	Rack voltage ≥ 4.28 × Number of Cell, 5 sec	Off
Under Voltage Protection	Major	Rack voltage ≤ 2.5 × Number of Cell, 3 sec	Off
Over Current Protection1	Major	Current ≥ 470A, 60sec	Off
Over Current Protection2	Major	Current ≥ 495A, 30sec	Off
Over Current Protection3	Major	Current ≥ 540A, 10sec	Off
Over Current Protection4	Major	Current ≥ 600A, 1sec	Off
Communication Failure1	Minor	No Communication, 30sec(Module and Rack)	On
Communication Failure2	Minor	No Communication, 30sec(Rack and System)	On

BMS controlled current limit

LITHIUM BATTERY BMS DUMP DATA VIA MODBUS

System Level Parameters Monitored

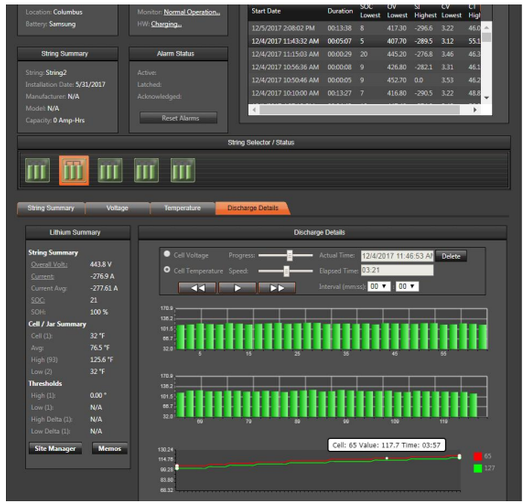
- Battery / system fault / mode status
- Monitor (BXE) status
- Overall string voltage
- Highest / lowest string voltage
- String current (actual/average)
- State of charge (SOC)
- State of health (SOH)

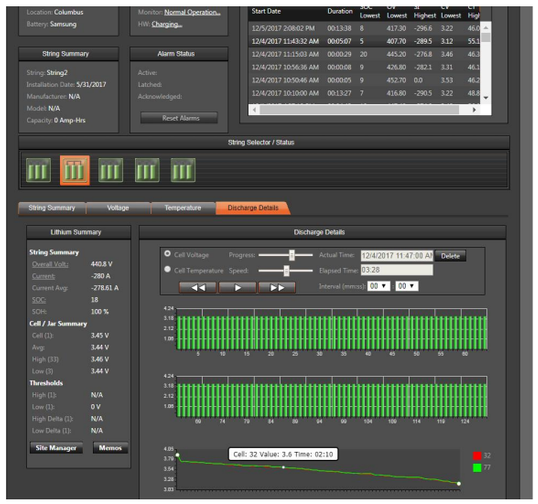
Cell Level Parameters Monitored

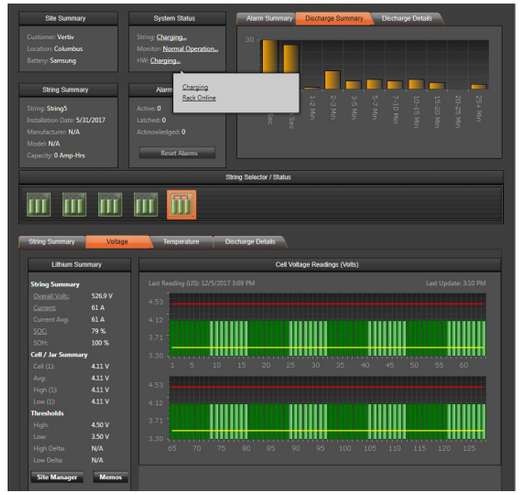
- Voltage
- Temperature
- Voltage balancing state
- Voltage : average, lowest, highest
- Temperature : average, lowest, highest

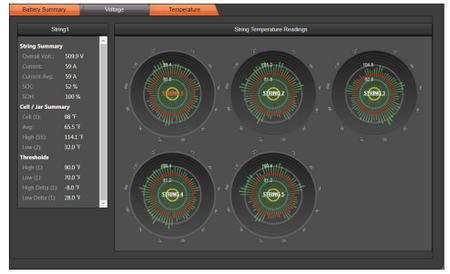
Notifications and Reports

- Configurable cell and system thresholds
- Store and playback of discharge events
- Trend analysis reports
- Alarm reports









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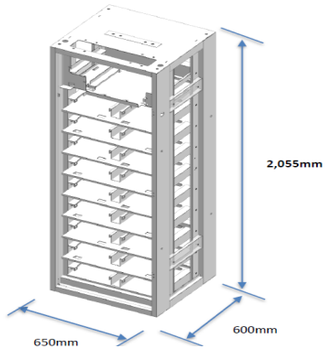
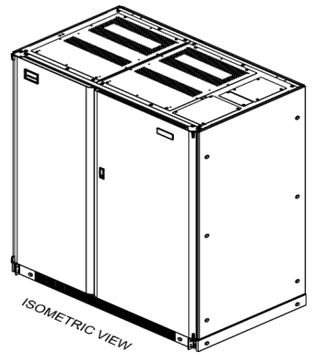
MAINTENANCE – READ THE BMS

Item		Comment
Environment	Temperature	- Check the temperature nearby battery - Check the trend of temperature.
	Humidity	- Check humidity nearby battery – outdoor container installation - Check the trend of humidity. - outdoor container installation
Battery Condition (BMS data)		- Check the battery condition information which logged by Monitoring BMS - Graph trend and check for any abnormality
Visual Inspection		- Check the battery room for smoke, smells of chemical, any leakage existed - Check for condensing - Visual inspection of the battery system - Check data and power cabling connection
Battery function	Voltage & Temperature Uniformity	- At float condition, read all cell's voltage and temperature for each rack
	Power Supply	- Check the status of redundant power supplies

YOUR CHOICE - LITHIUM-ION vs TPPL vs VRLA





	Samsung 128s	Enersys TPPL XE1040	Enersys HX-505
Time	159 kw@10 min 106 kW@15 min 201 kw@ 5min* **208 kw@1 min***	170 kw@10 min 134 kW @15 min 250 kw@5 min **356 kW@1 min**	159 kW @10 min 122 kW@15 min **230 kW@5min to 1.60vpc**
BMS Current limit	10 min.	none	none
DC disconnect	500a fuse/600a CB	600a or 800a CB	600a CB
Size	26”x24”	40”x30”	55”x 34”
Weight	**1200 lbs**	**4600lbs**	**5300 lbs**
Electrolyte	10.8 gallons / 3.3kg Li	66 gallons / 1292 kg Pb	66 gallons / 1232 kg Pb
Storage w/o charge	17 months	17 months	6 months
Warranty	10 years	5 years	3 years
Life	15 + years	7-10 years	4-5 years
Monitoring	Samsung BMS	Optional Alber	Optional Alber
Chemistry	LMO/NCM	TPPL VRLA	Lead calcium VRLA
Float voltage	4.2vpc	2.3vpc	2.3vpc
Relative Price	150%	110%	100%
Maintenance	40%	100%	100%

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