Marine Battery Management

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A Class Act, NP 39 #001

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Marine Battery Management Topics

- This is a HUGE area of technology – too big to cover in detail but most common issues addressed for the sake of general knowledge
- Battery Types
- Battery Basics
- Battery Operating Conditions
  - Under Way with Alternator DC Power
  - At Anchor
  - Dock / Genset AC Power
- Battery State of Charge Monitoring
  - How long before batteries are dead / drained?
- Battery Charging Systems
  - **Alternator**
  - Shore / Generator Charging
  - Solar Charging

Battery Types

- **Flooded Lead Acid (FLA)** – Traditional and longest history. **Must periodically add de-ionized water to maintain electrolyte level (Lead and Sulfuric Acid Batteries)**
- **AGM – Absorbent Glass Mat** – Glass fiber Mat holds electrolyte in a Lead Acid Battery –
  - Higher Power Density than FLA
  - Recharges more quickly than FLA
  - Sealed Battery
  - Easily replaces FLA with minimal cost impact (Change charger to AGM profile)
- **Lithium Ion (LiFePo4 – Lithium Iron Phosphate)** – Safe form of Lithium Batteries to prevent fires. Discharge to 25% remaining charge with minimal effects on battery lifetime.
  - High Power Density Vs FLA / AGM. Most expensive battery type available. Requires all new charging system or new programming
  - Sealed Battery
  - Only battery type with internal "Battery Management System (BMS)" electronics attached to control charge and discharge
  - Extensive Information on "LiFePo" batteries and charging systems by Ben Stein on PANBO.com
- **Firefly Carbon Foam AGM Battery** – Developed by Caterpillar Corp (Heavy Equip Mfr) –
  - Longer Service Life than FLA or Standard AGM (2X Greater number of charge / discharge cycles)
  - Rapid Recharge, Excellent Cold and Hot performance
- **Gel Lead Acid Battery** – Sulfuric Acid Electrolyte is mixed with Silica to make a thick gelatinous material that does not leak
  - Sealed Battery
  - Slow Recharging time - Requires specific chargers or charges with specific GEL charge profile available
  - Long Lifetime

Battery Basics

- All Lead Acid Versions of batteries should not be discharged lower than 50% under most conditions though AGM can sustain 40% remaining charge

- “LiFePo” Batteries can be discharged to 30% remaining capacity – increasing the available ampere-hours relative to FLA versions

- Overall Lifetime of ALL batteries is determined by the number of Discharge / Charge Cycles and the Depth of those Cycles
  - Charge from just 20 – 30% discharge has less impact on lifetime than 60% discharge (40% remaining)

- **NEVER combine different Battery Chemistries electrically!!**
  - **LiFePo operates at higher cell voltages and will attempt to dump large amounts of current into an FLA battery that is connected in parallel – serious overheating / fire / explosion possible**
  - Only connect batteries in Parallel / Series that are the same type:
    - FLA with FLA, GEL with GEL, AGM with AGM and LiFePo with LiFePo

- **Never charge a battery with the incorrect charging profile**
  - Never charge an FLA with a LiFePo profile or LiFePo with an FLA Charger
  - Serious damage to the batteries or charger or both can result

Battery Basics - Available Battery Power

- Battery Capacity is generally measured in AMPERE- Hours
  - 200 Ampere Hour (AH) FLA Battery can sustain 50% discharge or allow the use of 100 Ampere Hours before re-charge
  - An Ampere Hour means the battery delivers 1 Ampere of Electrical Current to flow for one hour. Batteries are measured in “Amps” and “Volts”
    - Amp = Flow – as in a hose (Gallons per hour example)
    - Volts = Pressure to cause current flow – like a pump
    - Watts = Power Delivered overall 10Amps X 12Volts = 120Watts of Power
  - AVAILABLE POWER Examples
  - **FLA Batteries** rated at 250AH can actually only provide 125AH before recharge to avoid low output voltage and reduced battery lifetime
  - **AGM Batteries** rated at 250AH can provide 150AH before recharge
  - **LiFePo Batteries** *rated at 250AH can provide as much as 200AH before recharge*

Batteries While Engine On – Alternator Load

- Under Way / Leaving the Dock / Docking / Anchoring
  - All Navigation Electronics
  - Side Thrusters
  - VHF Radios, AIS Transponder
  - Starlink, Cellular / WIFI Data Systems
  - Inverter – DC to AC for – Cooking Utensils, Computers, TVs etc
  - Battery Charging (Alternator Loading)
  - Navigation Lights
  - Interior Lights
  - Head, Water Pump
  - Background Items
    - Tank Monitors, Safety Monitors (Fire, CO, Propane)
  - Heating Systems – Hot water pumps / fans / Forced Air Furnace Blower and Fuel Pump, Heat Exchanger Pumps and Fans
  - Cooling Systems – Heat Exchanger Pumps and Fans
  - Refrigerator / Ice Maker
  - Anchor Windlass

Alternator Failure = All Stop!

Alternator may supply 40 – 50 Amperes at 13V while underway – 520Watts to 650Watts

1,700 Watts with 140Amp Inverter Load (120VAC at 14Amps) = Coffee Maker

Batteries at Anchor / Buoy

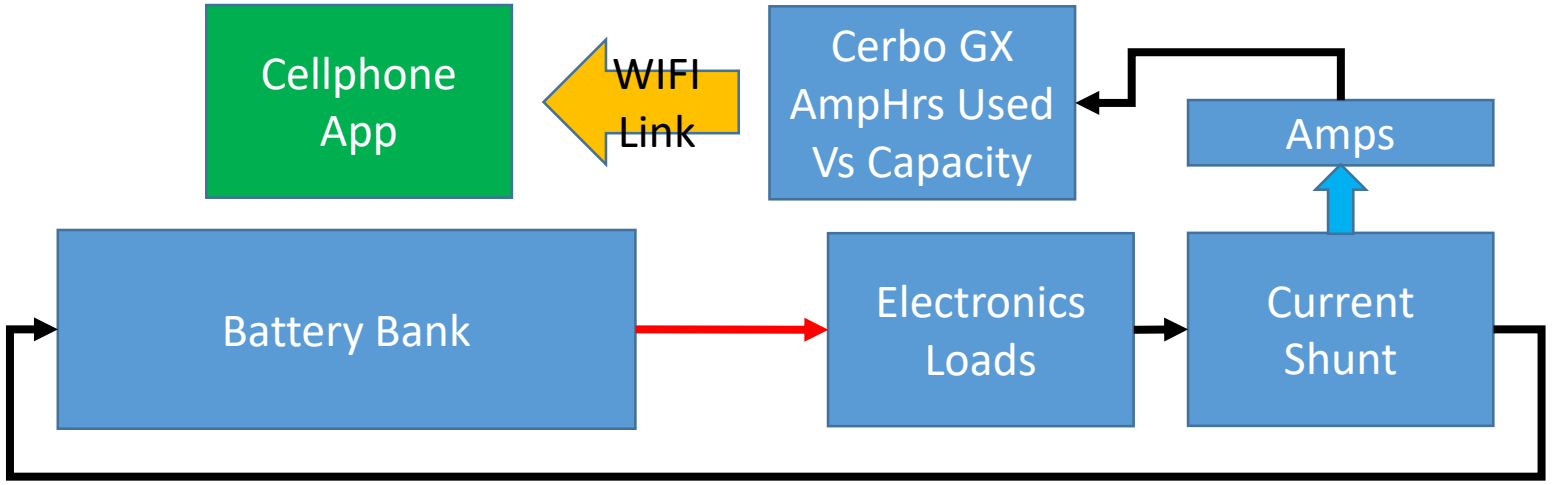
- **At Anchor**
  - Batteries are the only source of continuous power once “off the grid”
    - No Genset or Engine Operation
  - *Monitoring status of the batteries CANNOT be done by looking at the Battery Voltage Meter on DC panel!!*
  - Running critical items for “life aboard”
    - Interior Lighting
    - Anchor Light
    - Inverter – DC to AC – Coffee Maker, Microwave, Computer Chargers, Hair Dryers, Curling Irons, TVs
    - Water Pressure Pumps
    - Head Operation
    - Ice Makers
    - Refrigerators
    - Shower Sump Pump
    - Connectivity Items
      - Starlink / Routers / WIFI –Celluar Connections
    - Radio / Audio Streaming (SIRIUS) and TV
    - Charging Cell Phones, Tablets, Laptops
    - Background Operations
      - Bilge Pumps
      - Tank Level Monitoring (Black Water / Potable Water)
      - Monitoring / Safety Systems – (CO Monitors, Fire Detection, Anchor Watch etc)
- Many Items rely on Battery Power once engines / power cable are disconnected

How Long till the batteries are drained?

- Battery Banks are rated in Ampere-Hours
- 1 Ampere Hour is 1 Ampere of Electical Current Flow for 1 hour
- Typical 750Amp Hour AGM Batteries are capable of 350Amp Hours before recharge
  - LIFEPO Batteries of 400Amp Hour rating could provide the same 350Amp Hours before recharge (Smaller batteries and reduced weight)
- Typical Loads
  - Starlink at 5Amps per hour
  - 9CuFt Refrigerator at 6 amps per hour (When Compressor is on)
  - Water Pump / Head Flush – 20Amps (when running)’
  - Cabin Lights at 5Amps (LED) to 40Amps (high power filament lamps)
    - Changing to LED interior lights is exceptionally valuable
- When all are on for 1 hour the total Amp Hour Load is:
  - 5+6+20+40 = 71Ampere Hours
  - 350Amp Hour Battery bank can sustain that load for
    - 350AmpHours / 71 Amps = 4.9 Hours!!!
    - Not Long when at Anchor!!!
    - **Controlling loads on the battery bank is very important**

How to Monitor Battery “State of Charge”

- State of Charge => Time Remaining at present rate of discharge
- **“State of Charge”** is measured constantly over time to add up the Ampere Hours that have been consumed
  - Requires a “current shunt” – Device to measure amperes over time
  - Requires a small computer device to constantly add up each consumed ampere over time based on the output of the “current shunt”



Current Shunt is placed in the ground return cable for ALL Loads

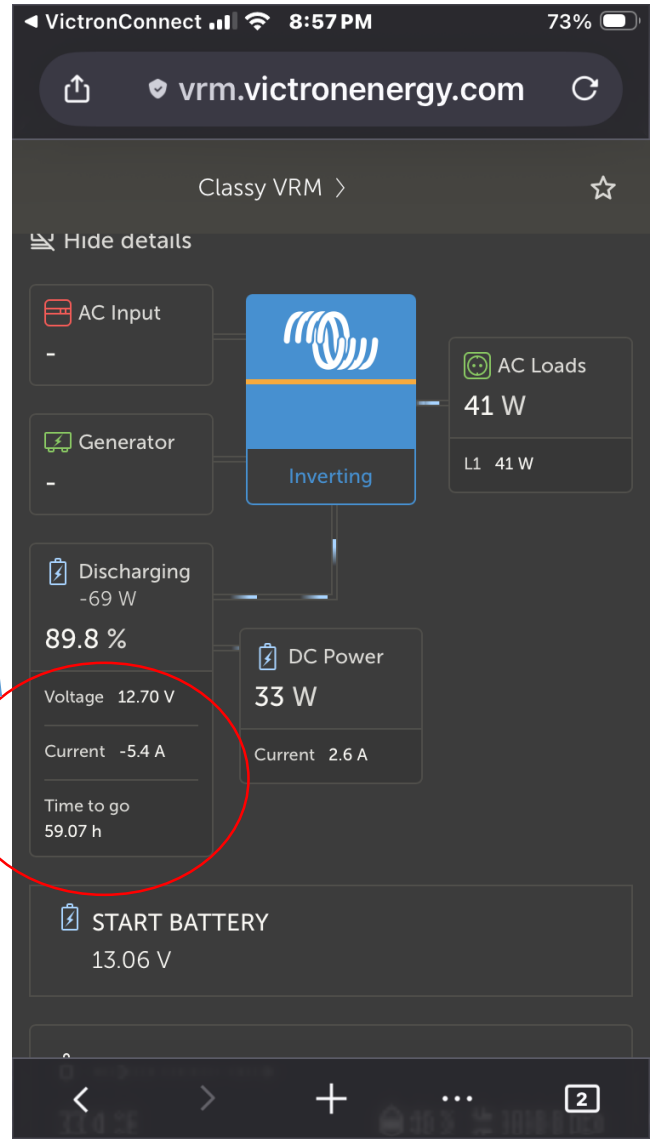
State of Charge Monitoring

How Long till Recharge is Needed?

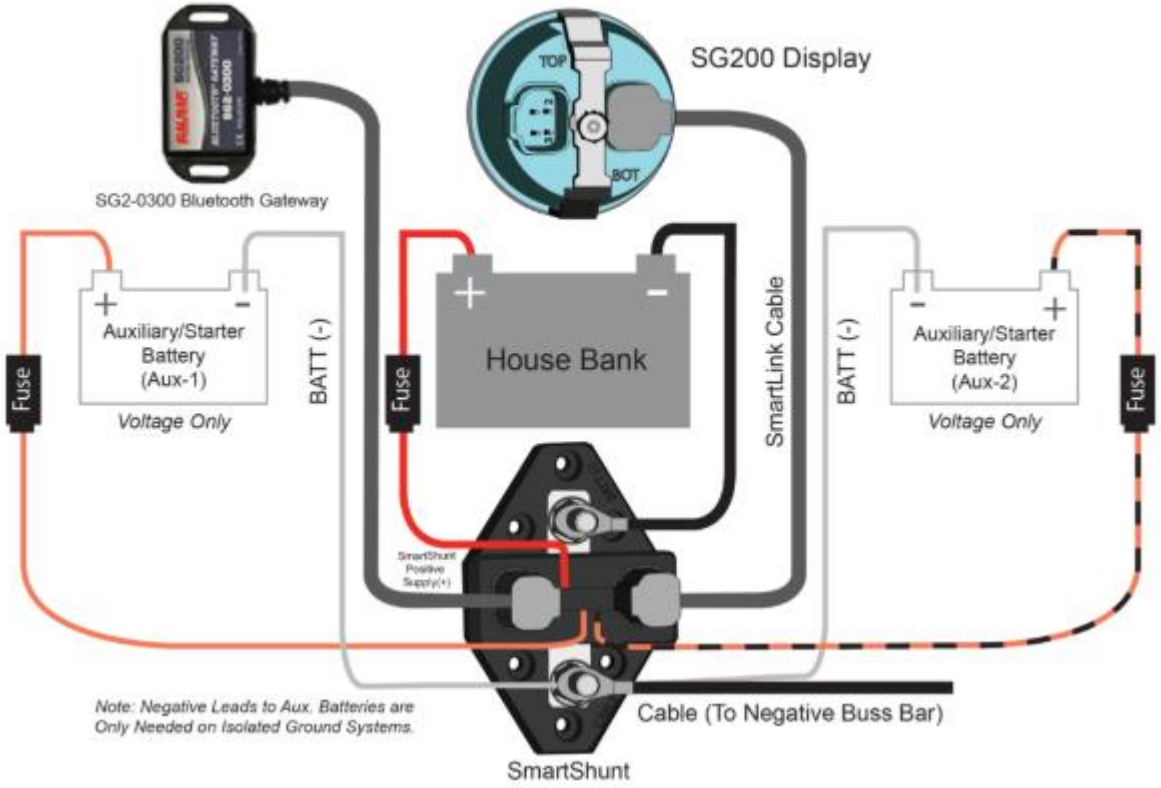
Victron Remote Monitoring shows “Time to Go” in hours and minutes

“Time to Go” assumes that the present rate of ampere-hours usage will remain the same on average over the predicted time remaining.

Provides a good estimate of battery condition and allows planning to run a generator or motor over some distance or use Solar Cells to charge the batteries.



Balmar SG200 State of Charge System



Smart Shunt Measures Amp Hours Consumed and Computes TIME REMAINING and State of Charge

Victron Energy State of Charge Monitoring

Cerbo GX provides Tank, Temperature, LIFEPO BMS Monitoring Via Bluetooth, WIFI, Ethernet and NMEA2000 Interfaces.

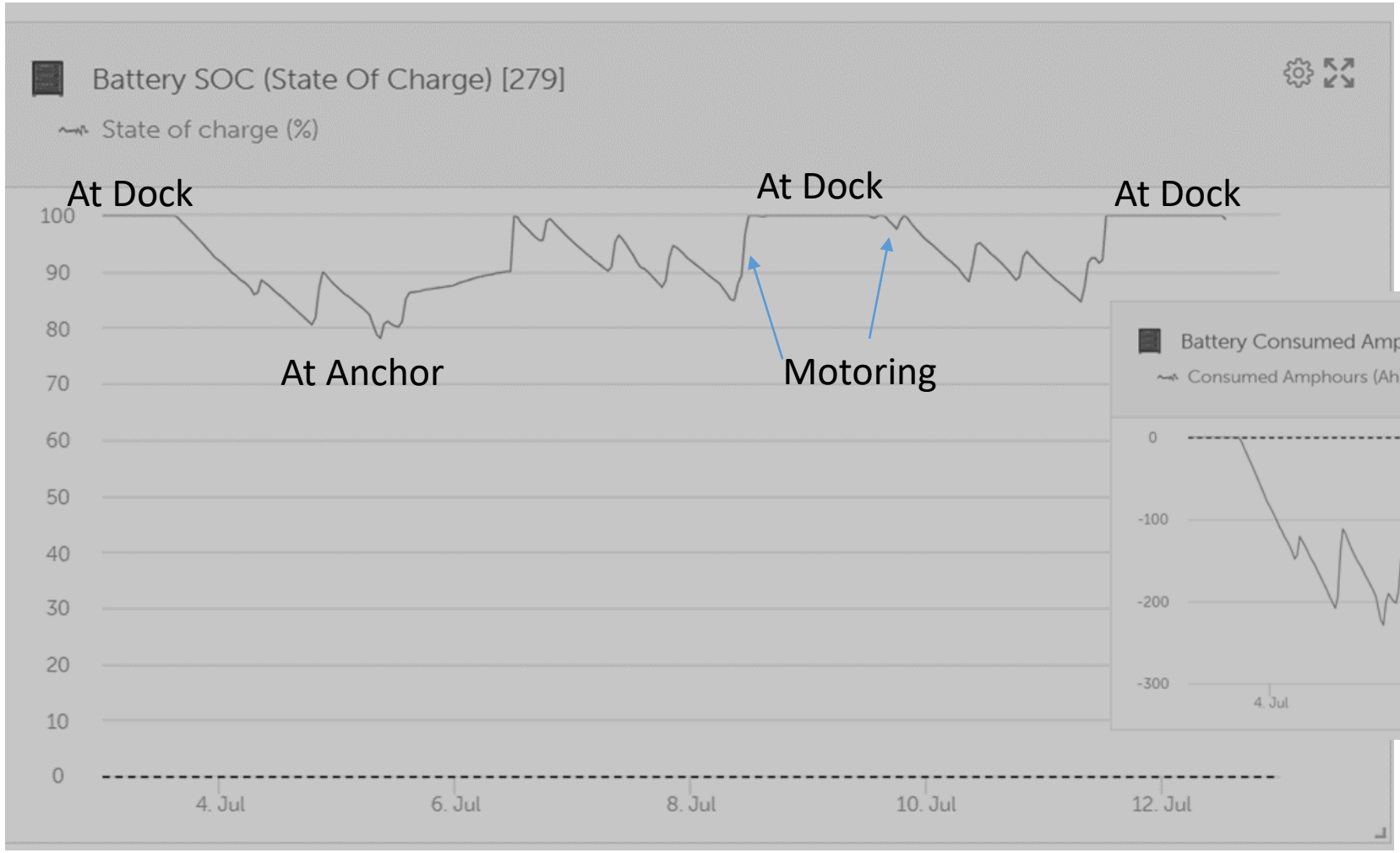
Interfaces with WS500 Smart Regulators

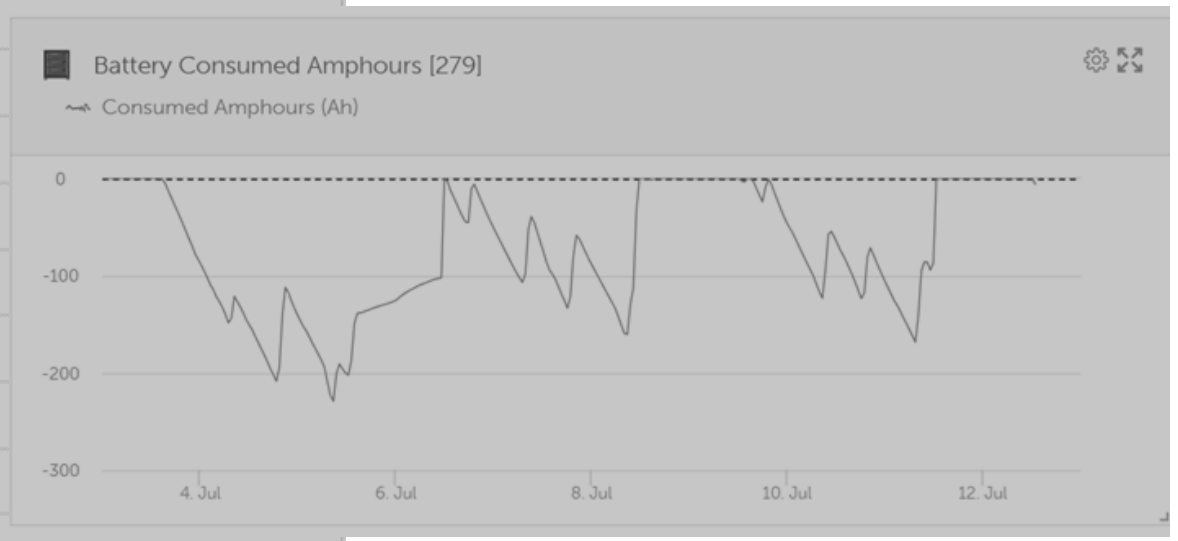
Collects Amp Hours Consumed from SMART SHUNT

Victron Smart Shunt MEASURES *Amp Hour Consumption* from Batteries that is totaled and reported by CERBO GX

Cerbo GX uses the consumed Amp Hours to predict TIME REMAINING for Battery Bank Computes STATE OF CHARGE

State Of Charge Data for 11 Days





Charging Batteries

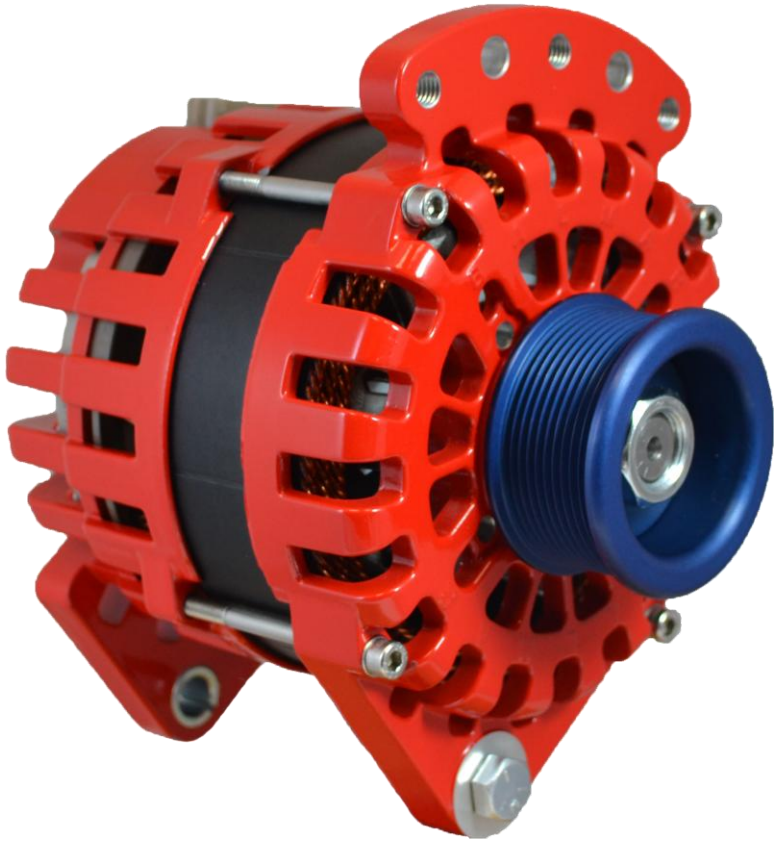
- **Engine Alternator**
  - **Standard “Fixed Alternators” at 14.4VDC**
  - **Smart Regulated Alternators at variable Voltage (Absorb Charge to Float Charge)**
    - **Specific charge profiles for each battery chemistry**
- Solar Panels – Solar Charge Regulators
  - Sun Powered Charging with specific battery chemistry charge profiles
- Genset / Shore Power Charging
  - AC Powered Battery Chargers with specific chemistry charging Profiles

Why Mess with Standard Alternator Regulators?

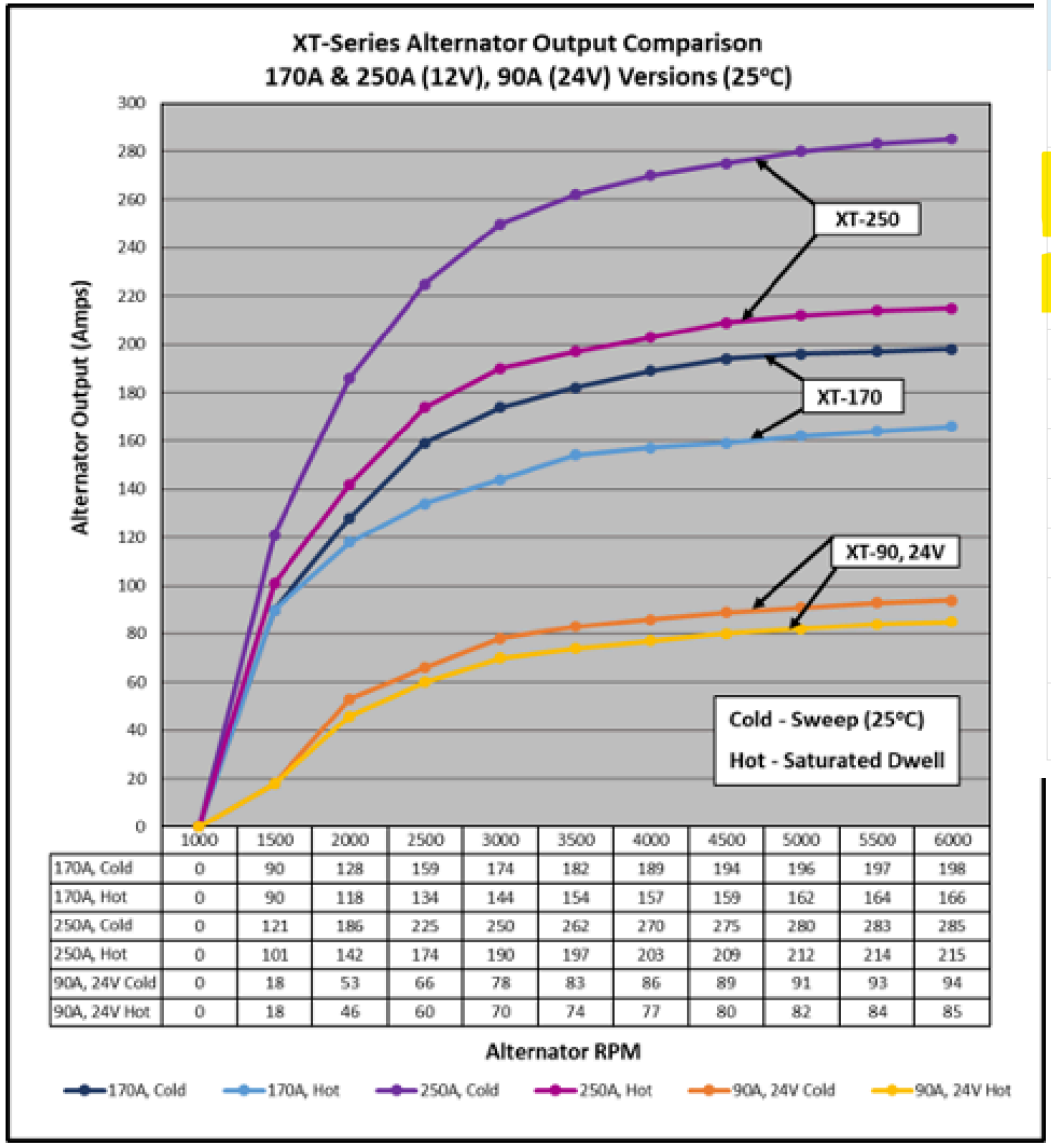
- LIFEPO Batteries (Lithium) cannot be charged with Standard Alternator!
  - Requires Smart Controller to provide LIFEPO specific charge voltage and current profile
- Standard Alternator Regulation is at a fixed Output Voltage of about 14.4V
  - Batteries require charge voltage to be reduced as full charge status is achieved
  - Marine Loads on Batteries and Alternator are dramatically higher than Automobiles
- Alternator Current Rating (100Amp, 160Amp, 200Amp etc) is for **INTERMITENT Loads ONLY**.
  - Typically load should be limited to ~50-60% of Max capability for extended periods
  - Case Temperature should be monitored and output reduced at elevated temperatures
  - *Alternators stressed to provide near maximum output levels for extended periods can overheat and burn up.*
  - Alternator Regulators can also fail and cause very high output voltages (16-20Volts) that can damage electronics
- As load on the alternator increases (pumps, Thrusters, Inverter) the alternator will dramatically increase output current trying to maintain 14.4V output

Bad Things Happen to Overloaded Alternators

Balmar Smart Alternator Components



Balmar Regulators and Alternators



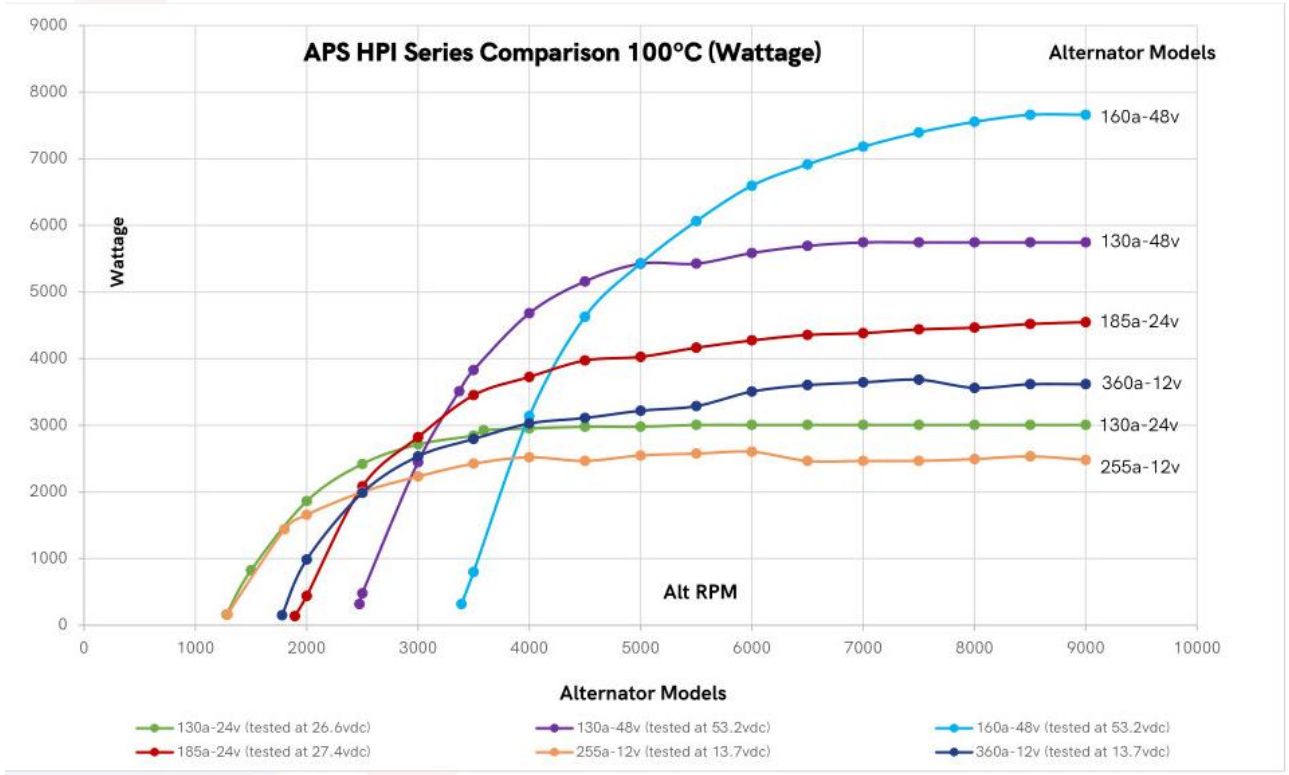
	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000
170A, Cold	0	90	128	159	174	182	189	194	196	197	198
170A, Hot	0	90	118	134	144	154	157	159	162	164	166
250A, Cold	0	121	186	225	250	262	270	275	280	283	285
250A, Hot	0	101	142	174	190	197	203	209	212	214	215
90A, 24V Cold	0	18	53	66	78	83	86	89	91	93	94
90A, 24V Hot	0	18	46	60	70	74	77	80	82	84	85

	Balmar Regulators				Digital Duo Charge	Dual Engine Centerfielder
Preset, Multi-Stage Battery Programs Part Number:	ARS-5	MC-618	MC-612-DUAL	MC-624	DDC-12/24	CFII-12/24
Universal Factory Program, Deep Cycle Flooded, Gel Cell, Absorbed Glass Mat (AGM) and Spiral Wound Flooded (Optima)	Yes	Yes	Yes	Yes	Yes	Yes
Standard Flooded, Voltage Halogen Systems, Lithium (LiFePO4), Carbon Foam AGM		Yes	Partial	Partial	Partial	Yes
Balmar Alternator Models						
6-Series Alternators (100A-120A)	Yes	Yes	Yes	Yes	Yes	Yes
XT-Series Alternators (90A-250A)		Yes	Yes		Yes	Yes
9-Series Large Case Alternators (140A-310A)		Yes	Yes	Yes	Yes	Yes
Multiple Alternator/Engine Configurations						
Dual Engine, One Alternator Each		Yes (2 qty)		Yes (2 qty)	Yes	Yes
Single Engine, Two Alternators			Yes	Yes (2 qty)	Yes	Yes

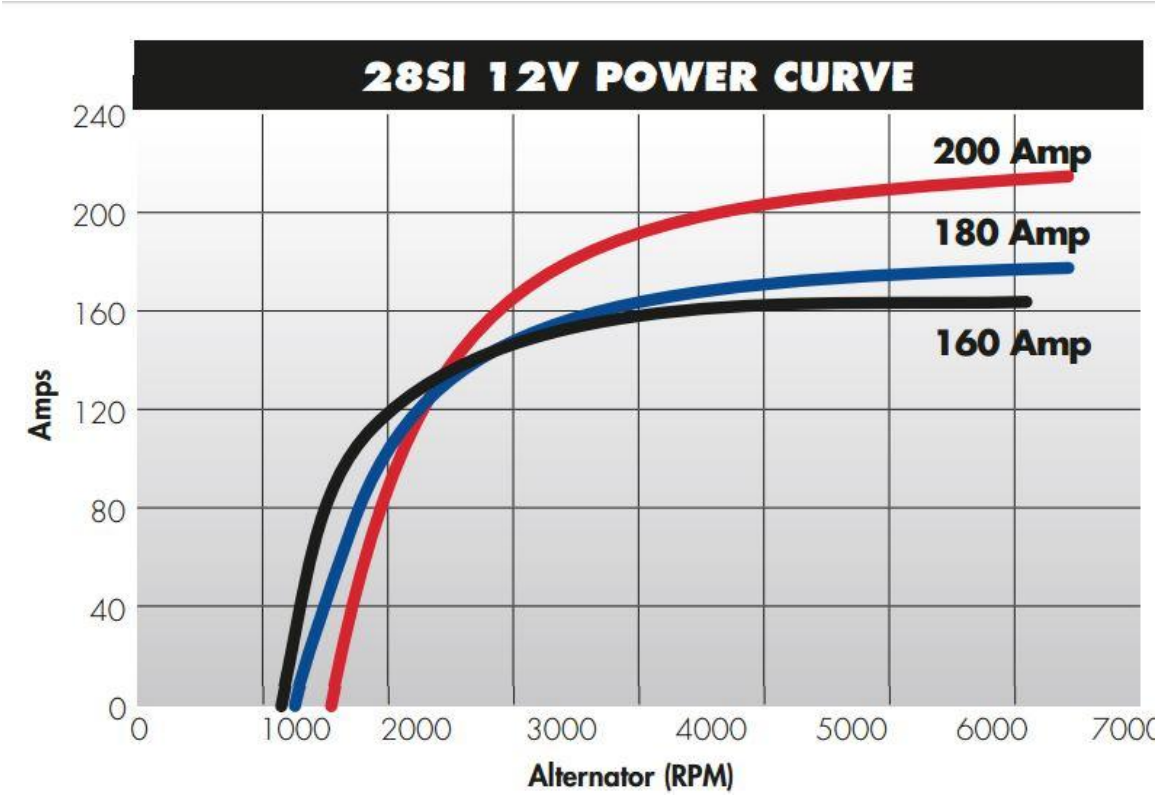
Externally Regulated Alternator Alternatives

AMERICAN POWER SYSTEMS, INC

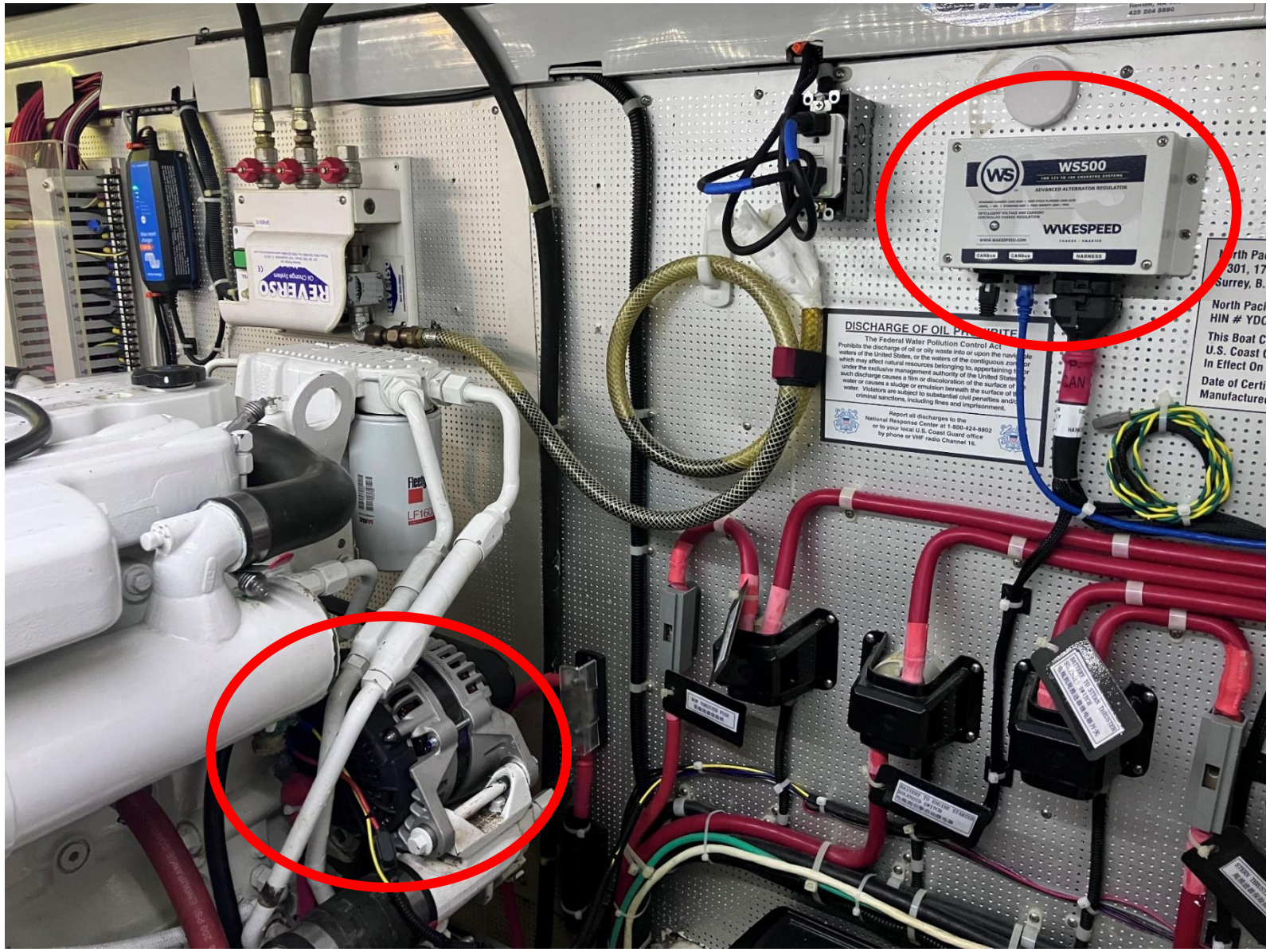
High Output Alternators - HPI Series



Delco Remy Alternators 24SI, 28SI



Wake Speed 500 Standard Installation



WS500 Paired with Delco Remi 28SI 200Amp Alternator – Drop in replacement for Standard 160Amp Cummins 24SI Alternator

Smart Alternator Controllers require the normal alternator regulator to be removed and for connections to the external smart regulator to be installed.

Programming the WS500 requires a USB B cable between an Android Tablet and the WS500 USB B connector (similar to old Printer cables).

WS500 PRO can be *monitored and programmed remotely* via an Android Tablet using a Blue Tooth Connection

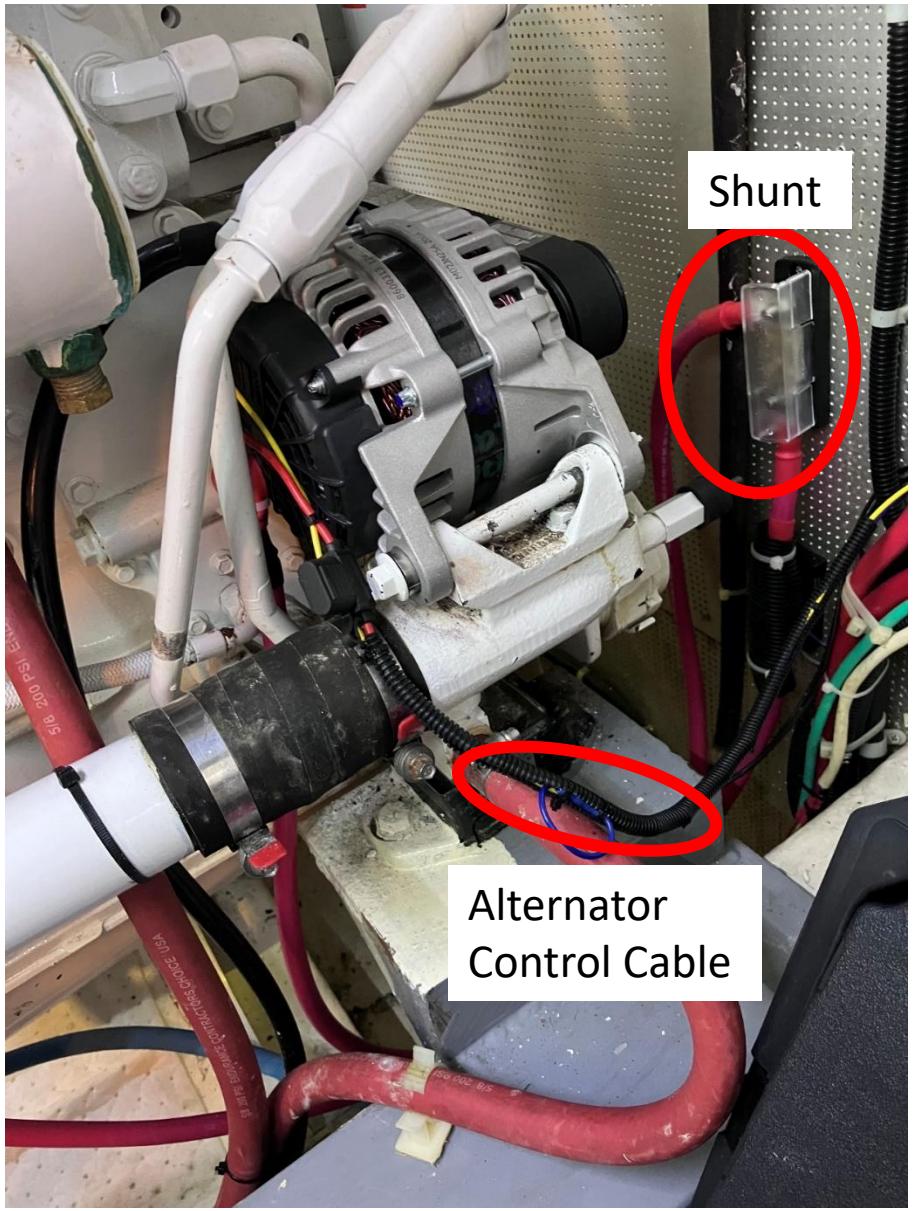
Wake Speed 500 – 500 PRO w Bluetooth

Wakespeed Regulators were developed locally in Anacortes WA and Supported Locally in San Juan Islands by company founder

Advanced Electronics Vs Balmar Regulators
* Alternators, Regulators, Victron Power Management Devices Available at Whatcom Electric and Battery in Bellingham WA

WS500 PRO with Bluetooth Monitoring and Programming

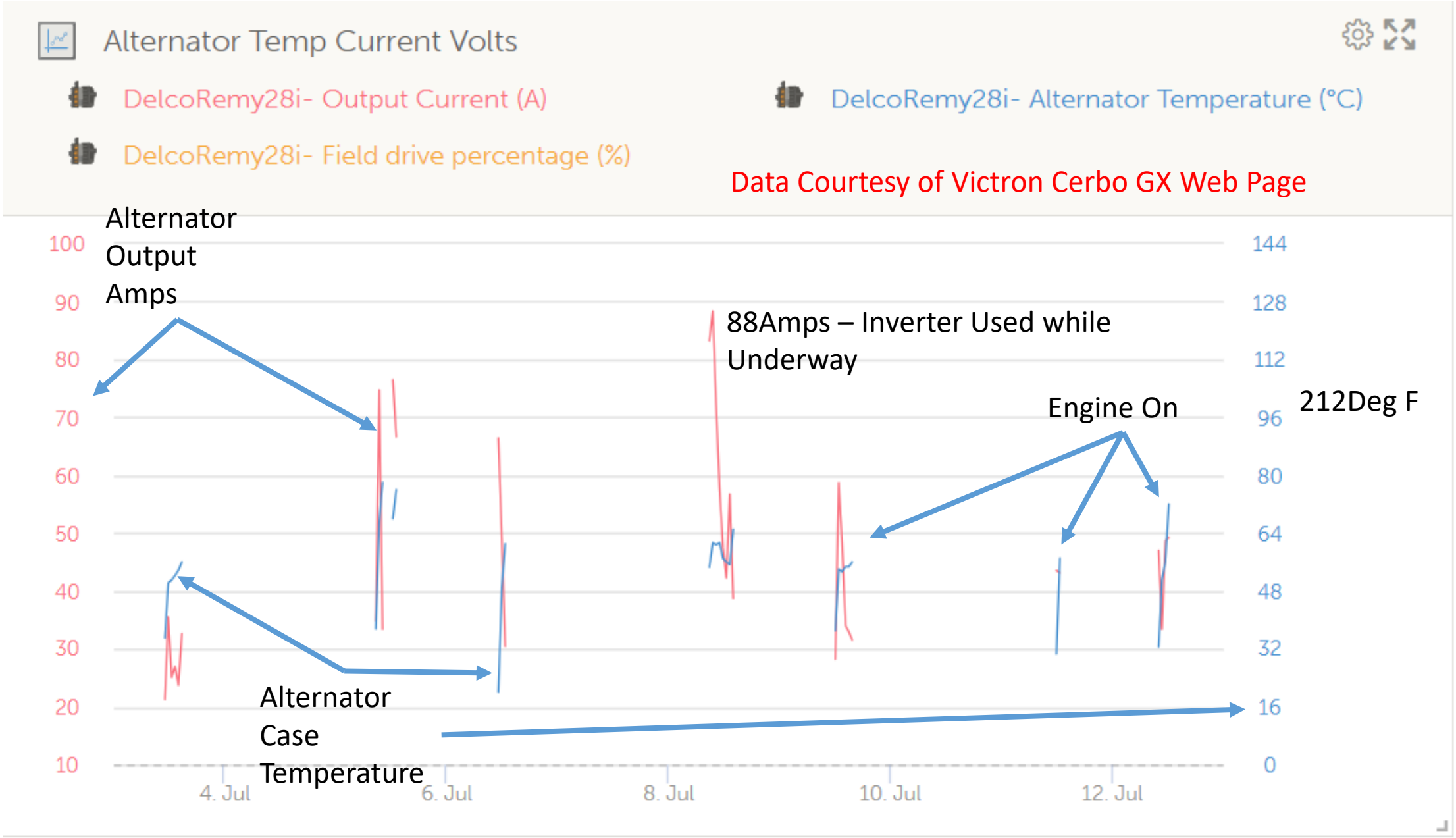
Alternator Wiring with External Current Shunt



- External Current Shunt measures actual ***<u>Alternator Current Output</u>***
  - Permits controlled charge current regulation to prevent overheating
- <u>Alternator Case Temperature</u> is monitored to prevent overheating
- <u>Charge Current</u> is controlled with Alternator "Field Drive" level

- WS500 Monitors <u>Output Current</u>, <u>Case Temperature</u> and <u>Output Voltage</u> of the Alternator to prevent Overheat while charging

Smart Alternator Data Over 11 Days On Cruise



Battery Voltage and Current for 11 Days

Solar “Background” Charging

Solar Array Panel

Solar Battery Charge Controller

Maintain Dinghy Batteries

Maintain Thruster or Dinghy Crane Batteries

Main source of charge when Genset has been removed and not motoring (Large LIFEPO Battery Bank)

Remote Monitoring of Solar Charge Status

Provides the option to constantly charge batteries so long as sufficient sunlight is present. Needs to be carefully integrated with Alternator / AC Chargers or used exclusively for batteries that are not part of the “House” pack

Summary

- Battery Chemistry determines Available Power (Ampere Hours)
  - Flooded Lead Acid Batteries – FLA, GEL, AGM, Carbon Foam
  - Lithium Iron Phosphate (LiFePo or LIFEPO)
- Battery Chemistry Determines Required Charging Profile
  - Voltage Levels Vs Current Absorbed by the Battery
  - Fully Charged Voltage Level Varies across Battery Types
- **LiFePO is the only battery with Internal Electronics**
  - Battery Management System (BMS) Electronics
    - Regulates Charge acceptance across each battery cell
    - Regulates Battery Discharge rate
    - Regulates Battery Temperature in Charge or Discharge
- Smart Alternator Regulators Charge Any Battery Chemistry
  - Stock Alternators do NOT charge LiFePO Batteries
  - Smart Regulator is programmed for the specific battery type
  - Prevents Alternator Overheating
  - Extends Alternator Lifetime

Summary

- Solar Charging is available for ALL Battery Chemistries
- Solar Charging requires a Matched Solar Panel and Solar Charge Controller
  - Controller Reduces Photovoltaic Array (Solar Cells) voltage to Battery Charge Level Requirements
  - Controller Follows required Battery Charge Profile
    - Voltage and Current Levels
- Solar Charging can be used for House Bank or Isolated Special Function Batteries
  - Crane / Davit Lift / Pot Puller Batteries
  - Thruster Batteries
- Solar Charging can be used with Multiple battery chemistries
  - AGM for House Bank Charged with Smart Alternator & Smart AC Charger
  - AND
  - Solar Charge for Isolated LiFePo High Load Batteries for Davits, Thrusters, Pot Pullers
    - Can be 12V, 24V or 48V Batteries
  - Or Solar Arrays with Specific Charge Controllers for Each Battery type