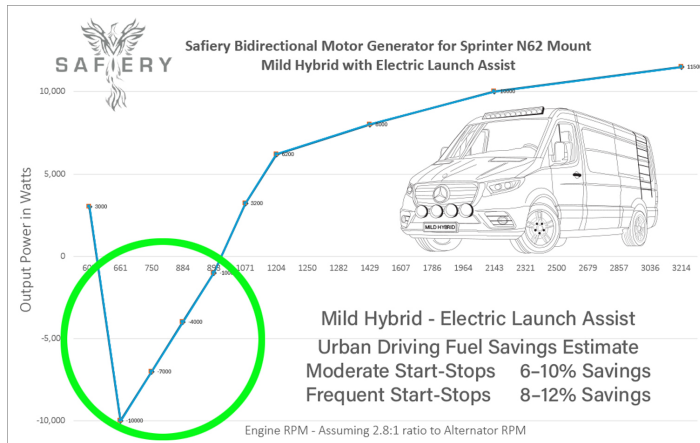




Scotty AI V3 and the Bidirectional Motor Generator

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Scotty Ai is protected by International Patent

Now with "Electric Launch Assist" Mild Hybrid



Scotty AI V3 and the BMG now appear in New Victron Cerbo GUI as "Alternator"
SEE IMAGE ABOVE WITH 779W FROM SCOTTY AI V3



- Bidirectional Motor Generator**
- Hybrid Stator Electrification
 - 10kW Motor
 - 10kW Generator

- Scotty Ai V3 (two models)**
- BMG Controller with Mild Hybrid
 - DC DC Bidirectional Converter
 - CAN based Battery Charger
 - Non-CAN Based Battery Charger



What is a Bi-directional Motor Generator and how does it differ from an Alternator?

- The Safiery Bidirectional Generator produces up to 240A at 48V at 90% Efficiency.
- Compare to traditional alternators which produce from 100A to 160A at 70% efficiency.
- A BGM is at its core a Permanent Magnet Generator which has rotor windings replaced by permanent magnets. Because there is no rotor excitation, rotor excitation losses – about 30% of total conventional generator losses – are eliminated. This results in high power density and small size with the highest efficiency at all speeds.
- A traditional alternator uses diodes and either an internal regulator to convert the AC power to DC or an external regulator like a Wakespeed.
- The BMG requires an inverter that converts AC to DC and to control the speed and torque of the motor. The dynamic response of this inverter controller far exceeds an alternator. It has:
- High Precision Control.
- High Energy Efficiency.
- Flexibility to operate efficiently over a wide range of speeds and load conditions.
- The Safiery BMG also uses HES Technology (Hybrid Excitation Synchronous). This combines permanent magnet (PM) excitation and electromagnetic excitation at the Stator (not rotor).
- This hybrid excitation mechanism overcomes the limitations of low output power at low RPM. The Safiery BMG outputs more than 2000W at idle compared to a few hundred watts with a traditional 48V alternator and remote regulator.
- Being Bidirectional feature means the Safiery BMG can operate as a mild hybrid. It can switch from generating power to being a motor and giving additional torque and power to the engine.

What role does Scotty AI play with the Bidirectional Motor Generator?

- Big power needs to be handled securely and at high speed. Scotty AI V3 becomes an integral part of the power system with the BMG providing this functionality:
- SCOTTY AI V3 determines if the mode of operation is “power generation” or “power motor as a mild hybrid” or at “idle”. It seamlessly switches between the modes.
- Communicates with CAN BMS lithium batteries and continuously calculates the charging parameters integrating these with the BMG control.
- Assesses non-CAN BMS lithium batteries and continuously calculates the charging parameters integrating these with the BMG control.
- Controls the BMG power at different speeds so when a vehicle or boat accelerates from idle, the torque is relaxed to have less load on the engine.
- Controls the BMG based on temperature rise of the inverter, motor speed and torque to give smooth power across the range of engine RPM.
- Controls the BMG so that the connected DC DC gives maximum power when called for by high power 12V or 24V devices like winches.
- Using the DC DC functionality, independent to the BMG, charges the same or an alternate 24V, 36V or 48V battery bank. The charging parameters can be completely different.
- Using DC DC functionality, independent to the BMG charges the starter battery so only the BMG is present on the engine with NO 12V or 24V alternator.
- Scotty AI V3 connects to the Victron VE.CAN bus with no negative impact to Victron control on the same bus.
- Scotty AI V3 can be compatible with RVC and share the BMG performance data on the RVC network.
- SCOTTY AI V3 has a connected App that is used for tuning with a patented auto-tuning feature as well as setting up charging parameters for the BMG and DC DC independently.

Watch Test Rig Videos on our Youtube channel.



Scotty Ai controls the Bidirectional Motor Generator to operate as a Mild Hybrid with Electric Launch Assist.

- Scotty AI V3 drives the mild hybrid functionality of the BMG:
- Every time your Sprinter starts moving from 0 km/h, the **engine must overcome vehicle inertia**—and it does this **inefficiently** at low RPM (typically <1200 RPM).
- Once the throttle is applied after idle and the engine RPM starts to rise, Scotty AI switches the mode of operation from “power generation” to “mild hybrid” motor power assist to engine.
- Your Scotty Ai and BMG now delivers **10 kW** of torque assist during this inefficient phase.
- This means **less diesel energy is needed** for initial acceleration.
- Once the Mercedes Sprinter engine RPM passes a configurable setpoint of RPM, Scotty AI switches the BMG to power generation mode and winds it up progressively to 8kW and up to 3kW from the DC DC independent function. A conservative estimate is 10kw of power at cruising speed.

How much energy comes from the 48V battery and what is the impact on battery life?

- $10 \text{ kW} \times 4 \text{ seconds} \times 30 \text{ launches/hr} = \sim 334 \text{ Wh/hr}$ of electric launch energy
- For urban delivery van with 10 hours/ day that's 3,340Wh of battery energy per day
- 4 x Safiery Solid State Lithium batteries are 11,120Wh capacity
- However, when the Sprinter is driving over 1200RPM the replenishment energy is the same so if the vehicle is over 120 secs an hour, the replenishment energy matches the mild hybrid power.
- Safiery Solid State Lithium batteries have a 10,000 cycle life. A cycle is contiguous use of energy to 1C. 1 cycle every 3 days. It would be 3,330 days to 80% battery capacity – about 9 years.

What are the fuel savings and \$ per year estimated savings?

- | | |
|-----------------------------------|---|
| ▪ Daily distance | ▪ 200 km |
| ▪ Drive type | ▪ Urban (stop-start, low avg speed) |
| ▪ Baseline fuel consumption | ▪ ~14–16 L/100 km |
| ▪ Total daily fuel use (baseline) | ▪ 28–32 L/day |
| ▪ Fuel price | ▪ \$2.00/L (AUD est.) |
| ▪ Hybrid assist | ▪ 10 kW from 0–1200 RPM per stop |
| ▪ Fuel savings from assist | ▪ 8–12% typical in urban use |

Fuel Usage (Baseline)	Savings (%)	Fuel Saved (L)
28 L/day	8–12%	2.24–3.36 L
32 L/day	8–12%	2.56–3.84 L

At \$2.00/L, your daily savings would be:

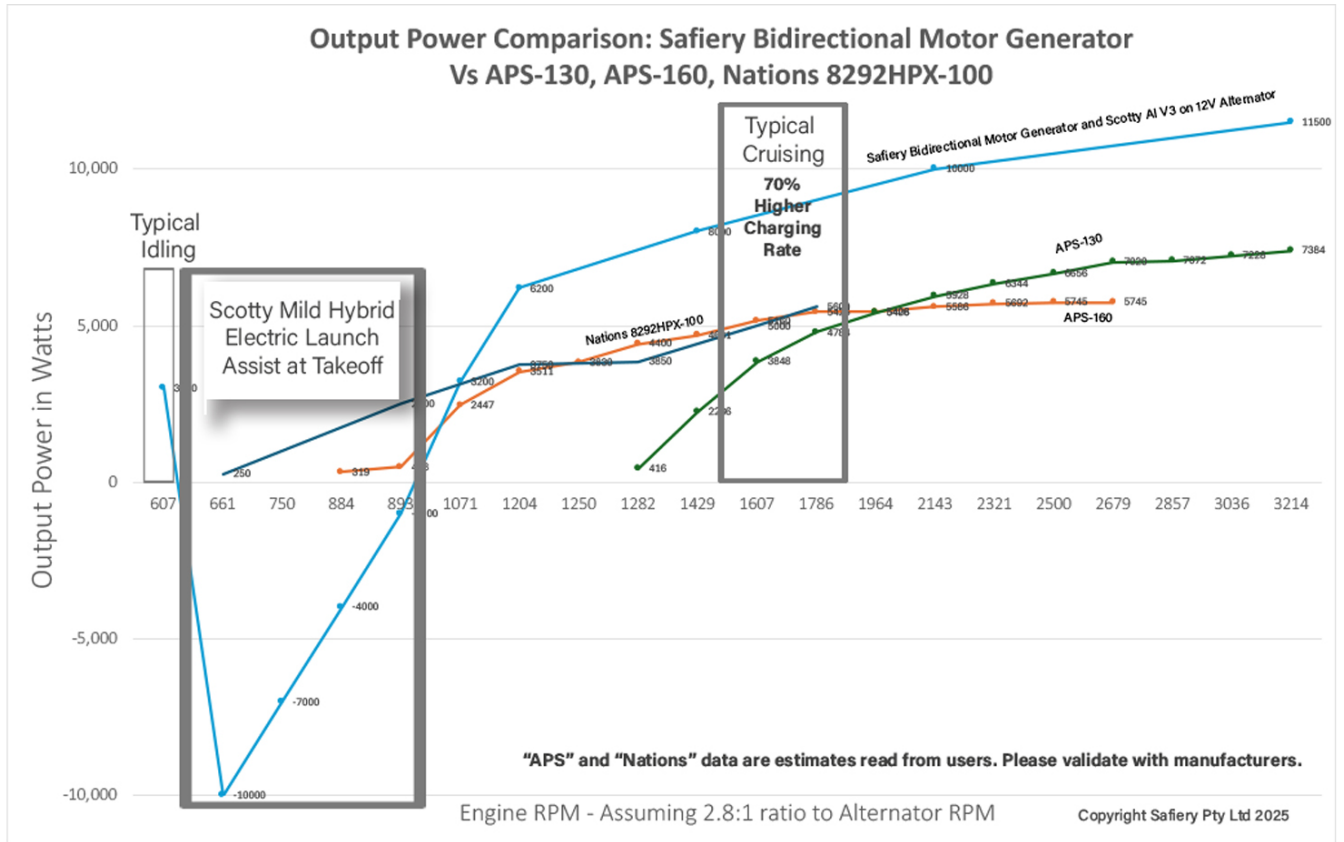
- Low estimate: $2.2 \text{ L} \times \$2.00 = \$4.40/\text{day}$
- High estimate: $3.8 \text{ L} \times \$2.00 = \$7.60/\text{day}$

Annual Fuel Savings (Assuming 250 working days):

Fuel Saved per Day	Annual Savings
2.2 L	\$1,100/year
3.8 L	\$1,900/year



How does BMG compare to other high power alternators?



Comparison when fitted to 2025 Mercedes Benz Sprinter V6	Safery Bidirectional Motor Generator and Scotty AI V3	APS130*	APS 160*	Nations 8292HPX-100*
Alternator/ Motor Efficiency	90%	Not Published but estimate is less than 80%		
Inverter Fitted and its Efficiency	94%	Uses Diodes which are low efficiency and External Field Current Regulator		
Estimated Power Output at Engine Idle	3000W	Small	None	Small
Mild Hybrid with Mercedes Benz Sprinter N62	Yes	No, not possible.		
Estimated Power cruising speed 1800 engine RPM	9000W	6000W	5000W	6000W
Maximum Output	11000W	6000W	7400W	6000W
Patented Auto-tuning	Yes	No		
Limp Home Mode if CAN connection to Battery lost	Yes Up to 4kW	Yes Power level not published		
Multipoint temperature Monitoring	4 temperature measurements	1 temperature measurement		
Bidirectional 48-12-48 included	Yes at 1500W or 3000W at 12V	Requires separate DC DC		
Isolated Negative Victron Smartshunt Connect Bluetooth on Sprinter	Yes On negative from BMG	No Only at Battery.		





Second Alternator Position or Only One Unit replacing Factory Alternator:

- SCOTTY AI V3 can be mounted outside of the engine bay with a waterproof NMEA style connection to the BMG data plug. The actual 48V power goes directly from the BMG to the auxiliary 48V battery system. In this setup, the BMG would be in a second alternator position in the vehicle or on the marine engine. On the marine engine, if the engine power is low, the second alternator position is opposite the primary alternator to balance the load on the crankshaft.
- SCOTTY AI V3 can be mounted outside or inside the engine bay with the BMG replacing the factory alternator and the 12V or 24V DC-DC feed from SCOTTY AI V3 charging the lead acid starter battery. In this scenario, there is just one unit, the BMG, attached to the engine. The additional charging from a second factory 12V or 24V alternator is then not possible. Mild Hybrid and Free Power Control described in this document is still possible.

Charging Control at 48V from the BMG:

- SCOTTY AI V3 drives the BMG with real-time torque and speed whilst monitoring the output Voltage and Current and making control adjustments.
- SCOTTY AI V3 determines the optimum voltage and current charging parameters based on battery voltage, state of charge, charge current limit and temperature. Should the battery temperature be below the safe charging limit, SCOTTY AI V3 will not charge.
- SCOTTY AI V3 changes the real-time torque and speed when the battery approaches maximum State of Charge; and/or the BMS Charge Current Limit indicating the battery is approaching maximum charge state.
- The BMG is a vector controlled permanent magnet generator with additional windings on the stator for high power output at idle. There are no windings on the rotor, it is completely inlaid with permanent rare earth magnets. There are no diodes as with conventional alternators. As a result, efficiency of the generator is 90% and the inverter/controller connected is 94% giving a combined 85% round trip efficiency. Compare that to a traditional alternator at 60-70% when hot. External regulators like Wakespeed 500, Balmar or Zeus control the field current on traditional alternators. They don't achieve this level of efficiency and are a field control add-on. There is no comparison.

Safety is number one feature: Load Dumps are controlled:

- SCOTTY AI V3 stops the BMG should the battery voltage start to reduce suddenly indicating Battery relay is opening to stop over charging.
- Safieri use Manual Service Disconnects (from EV Industry) installed on Safieri 48V battery circuit and connect the High Voltage Interlock feature of these MSD's to SCOTTY AI V3 to prevent the BMG from running should the battery be isolated. This is a key requirement as if solar is connected, the 48V reading may remain high. Without an interlock, arcing and fire risk may occur.
- In the unlikely event the battery relay opens quickly before the BMG is completely shut down, the stored energy is called a "load dump". The digital response speed of SCOTTY AI V3 is in milli-seconds resulting in a tiny amount of contained energy. This very small, contained energy reverts through SCOTTY AI V3 bi-directional feature to the 12V starter battery or if not connected dispersed with a max controlled voltage to 12V loads. This is a complete contrast to traditional 48V alternators and external regulators which control of field current with more than a 1 second delay. In that amount of time, the contained energy of the "load dump" is considerable. Generally, the battery/controller cannot respond fast enough should the battery relay open in these traditional alternators with external regulators unless pre-warning is issued 2 seconds ahead of time. This is hard to guarantee.



- SCOTTY AI V3 stops the BMG when an alarm is sent from the battery BMS and/or the BMS Charge Current Limit is reached and/or the BMS sends a reduced Charge Voltage limit indicating the battery is approaching maximum charge state. There is also a feature-in wire to stop charge.
- SCOTTY AI V3 stops the BMG when temperature approaches setpoint set in APP protect the system from overheating. It starts to derate at maximum BMG temperature less 10C.

Charging Control at 48V from 12V Starter Battery and factory alternator:

- SCOTTY AI V3 drives charging either to the same connected 48V battery or an entirely independent 48V battery system using the in-built DC DC feature. If connected to the same 48V battery as the BMG then control is synchronised between the two units with exactly the same battery control and safety provisions. In this case the power output of the combined unit is maximised to approx. 10kW if the 12V factory alternator is 250A and above. The full functionality is described in the manual and supported by a configuration and real time monitoring app. This is a standard included feature. The high output 12V alternator is either factory provided or an optional after-market unit.
- SCOTTY AI V3 can charge as described above from either a 12V starting system or a 24V starter and battery system.
- SCOTTY AI V3 determines the optimum voltage and current charging parameters based on battery voltage, state of charge, charge current limit and temperature.
- SCOTTY AI V3 changes charging parameters when the battery approaches maximum State of Charge; and/or the BMS Charge Current Limit indicating the battery is approaching maximum charge state.
- SCOTTY AI V3 changes charging parameters should the user select "Soft, Medium, or Hard" from the optional touch display

Power Control to either 12V or 24V starter battery and /or loads:

- SCOTTY AI V3 delivers the lower voltage at a regulated maximum "camping voltage" set by the user in the App.
- SCOTTY AI V3 can charge a low voltage 12V or 24V battery with a selected charge profile as an option selected from the App. This is reserved for when the BMG is only charging device.
- SCOTTY AI V3 controls the maximum power set by the App at a controlled max voltage and discharges to a minimum voltage on the connected 48V side battery to prevent this battery from discharging completely. If the starter battery is connected, a 12V or 24V Smart Battery Protect unit (optional) prevents it from discharging completely.

Fault Handling:

- SCOTTY AI V3 displays fault codes on the connected App.
- The status LED changes from pulsing green to red if a fault occurs.
- Should the CAN or battery communication system fail, the BMG can operate in a limp home mode with minimal output yet enough to drive a 48-12V or 48-24V DC-DC to power an engine if the BMG replaces the single factory alternator.



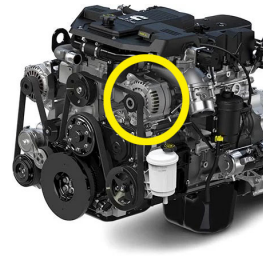
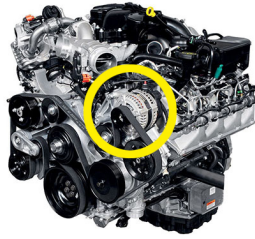
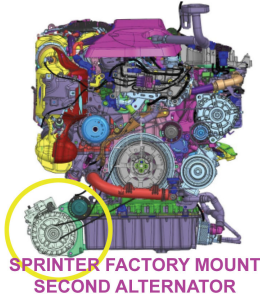
- SCOTTY AI V3 is connected to VE.CAN
- Both Scotty AI DC DC and the BMG appear as "alternator" in the left hand square of new Victron GUI
- When Scotty and/or BMG are off, DC loads appears for the DC DC power from from High Side of Scotty to Low Side. This is typically 48V > 12V



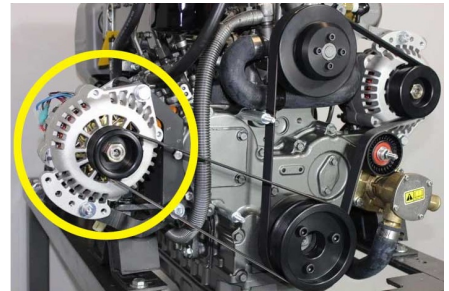
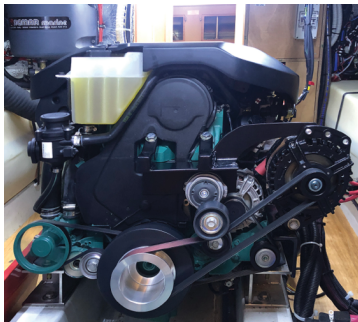
Engine Compatibility

- Currently available is Sprinter, Yanmar and USA truck engines pad mount
- Scheduled to release Q2/Q3 2025 is J180 Mounts for marine followed by LC79 as factory replacement single alternator with BMG; RAM 2500, F250 and GMC second alternator mounts.
- Scheduled release Q2Q3 2025 Isuzu double mount 24V factory + 48v BMG.

Vehicle Pictures below: Sprinter, Ford, Cummins



Marine Pictures below: Volvo, Yanmar engine second alternator position





	Comparison of BMG to Old School Alternator	Hybrid 48V 300A Peak Bi-directional Motor Generator with Scotty AI (BMG)	Traditional 48V 130A Alternator with <u>Wakespeed 500</u> remote field control.	Winner
Technology	"Alternator" Type	Hybrid Excitation Synchronous Generator (permanent magnets + hairpin windings)	Field-excited rotor only	BMG
	Rotor Design	16 permanent magnets + excitation windings	Field windings only	BMG
	Power Density	1.65 kW/kg (advanced hairpin)	Lower due to round-wire winding	BMG
	IP Level	Brushless Motor: IP25. Waterproof Inverter: IP6K9K	Generally Brushed IP23 or lower	BMG
	Dual Stator Design	Dual three-phase, 30° shifted	Single three-phase	BMG
	Ripple Current Reduction	Significant (30° phase shift)	Higher ripple	BMG
	Noise Vibration Harshness Performance	Optimized (low ripple and torque smoothness)	Higher NVH	BMG
	Efficiency	Higher (permanent magnets + hairpin winding)	Lower (field-excited losses)	BMG
	Fault Tolerance	Dual stator allows operation in partial failure	Single stator, no redundancy	BMG
Performance	Peak Generator Power	12 kW	6.2 kW	BMG
	Peak Efficiency	BMG is 90% Inverter Controller is 94%	60–70%	BMG
	Power at Idle (engine ~600RPM)	2-2.7kW	300-500W Typically	BMG
	Continuous Power Hot	≥7.0kW	5~7.0 kW	BMG
	Maximum Speed	18,000 RPM	~8,000–10,000 RPM	BMG
	Operating Temperature	-40°C to 105°C	-20°C to 80°C	BMG
	Lifetime Expected	10 years, 300,000 km, 8,000 hrs	5–7 years, 150,000–200,000 km	BMG
Safety	12V, 48V Negative Isolation to Earth	Yes	No	BMG
	Integration with Factory 12V or 24V Alternator	Full Integration for added power as solar backup at idle	None	BMG
	Load Dump Protection	Inverter/motor diagnostics, 100% load dump protection	Limited and depends on Battery	BMG
	ISO 26262 ASIL B Automotive Safety	Compliant	Not compliant	BMG
	Insulation Grade	Grade H (180°C)	Grade F (155°C)	BMG



Safiery Model	SHSA4801 – Max 300A Peak at 48V	SHSA4802 – Max 240A Peak at 48V
Operation Voltage	24V or 48V Power up to 60V	
Operating Temperature	-40°C ~ 105°C	
Maximum DC Output	300A@48V	240A@48V
Application	Trucks	4WD, SUV, Sprinter and Vans, Marine Engines
Continuous Power	8.9 KW @ 25°C (ambient temp),6000RPM 7.3 KW @ 55°C(ambient temp),6000RPM	8.2 KW @ 25°C (ambient temp),6000RPM 6.6 KW @ 55°C (ambient temp),6000RPM
Turn-on Speed	500 RPM engine speed 80A@1500RPM alternator speed at 48V	500 RPM engine speed 70A@1500RPM alternator speed at 48V
Maximum Speed	18000 RPM Intermittent	
Control Mandatory Requirement to Operate	Scotty Ai V3 3000W or 1500W Model; RVC is available for Sprinter	
24V or 48V Battery Compatibility	Most BMS with CAN controlled Lithium Batteries. Lithium Batteries without CAN BMS can be managed but a stop charge function on these batteries must be available. Scotty Ai V3 manages many non compliant Lithium battery banks.	
Temperature Protection	Yes	
Load dump Protection	Yes	
Weight	9 KG	7.7 KG
Dimension	164 L x 150 D mm	156 L x 150 D mm
Overall Efficiency	85%	
Cooling	Integrated Dual Fans	
Rotation	Clockwise/ Counter Clockwise	
Pulley	PK belt specification	
Case Construction	Cast and Billet Machined Aluminium Alloy	
Mild Hybrid Mode	Yes Available as an option see body of document for requirements	
Isolation Level	H Insulation Class H is rated to withstand a maximum operating temperature of 180°C	
IP Level	Motor: IP25 Inverter: IP6K9K	



Additional Safety Levels

Functional Safety: ISO 26262 ASIL B

- What It Means:
- Compliance with ISO 26262 ASIL B ensures the system meets safety requirements for automotive applications where moderate safety-critical functions are needed.
- Comparison:
- Traditional alternators are not designed to meet functional safety standards like ASIL B.

Inverter and Motor Diagnosis and Protection

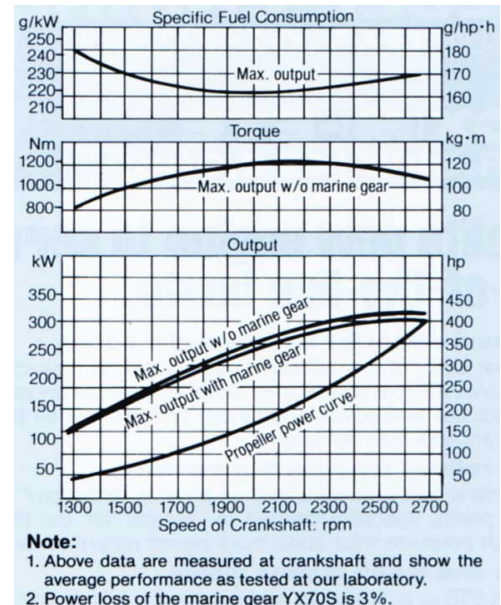
- What It Means:
- Includes built-in diagnostic tools for the inverter and motor to monitor performance and detect faults (e.g., overvoltage, overcurrent, or overheating).
- Provides protection against load dump (a sudden voltage spike when the battery is disconnected), ensuring system stability and longevity.
- Comparison:
- Traditional alternators with Wakespeed 500 lack integrated motor diagnosis and load dump protection; they depend on external BMS control for this.



Impact on Fuel Consumption with a high output BMG on Marine Engines

Key Insights Using Performance Curves of Yanmar 420CX as Example

- The BMG load at maximum output has a minimal adverse impact on overall system efficiency at cruising speeds.
- In some cases, adding the BMG load improves the fuel efficiency of the engine by moving it closer to its optimal operating range.
- Adding a 9 kW BMG load to the Yanmar 420 CX engine at cruising speed increases fuel consumption by approximately 2.74 liters/hour or about 5.4%.
- This is a relatively small impact, demonstrating the efficiency of using the BMG within the engine's cruising efficiency range.
- There is no impact on boat speed because of the white space to propeller load.



The Torque Curve

- Torque is the twisting force on your prop shaft. You could have all the power in the world, but if the shaft didn't spin you'd have no torque and no go. Torque is actually defined with the formula: Torque, KGM = $(975.175 \times \text{kW}) \div \text{RPM}$
- The torque curve shows the torque generated by this engine at various RPMs. The interesting thing is that maximum torque on normal internal- combustion engines doesn't occur at maximum engine rated power and RPM. In fact, the torque curve of the 420 CX Yanmar is pretty typical. The maximum torque occurs at about 77 percent of maximum RPM, or 2,100 RPM. Indeed, on most engines maximum torque falls somewhere between about 55 percent and 80 percent of max RPM. (Light gas engines tend to have peak torque at lower engine RPMs and heavy diesels at higher RPMs.) The units for the torque curve are in kgm (kilogram meters) and Nm (Newton meters). This is the metric equivalent of pound feet. We're not particularly concerned with the absolute numbers; however, we're simply interested in where torque is highest.
- In simple terms, the 420 CX Yanmar is delivering the most oomph per gallon of fuel consumed from 2,100 RPM. This wouldn't be a bad low-cruising speed, but you don't unnecessarily want to limit operating speed this much. Let's see how fuel consumption fits into the picture.

Specific Fuel Consumption

- The specific fuel consumption curve reads—as is often the case—in rather inconvenient units. In this instance, in grams per kilowatt per hour (g/kW). For the moment, though, what we're really interested in is the shape of the curve and where fuel consumption is lowest for the output power and torque. In other words—just the opposite of the power and torque curves—the best spot on the specific fuel consumption curve is where it's lowest. For the 420 CX Yanmar, this is at 2,000 RPM.
- Since we already know that the optimum torque is at 2,100 RPM, you could say that you'd get the most bang for the buck out of this engine at 2,050 RPM — a combination of best fuel efficiency and most speed.
- As for the curve of specific fuel consumption, this is inconvenient in more ways than simply converting grams per horsepower hour to sensible units such as liters per kilowatt per hour or gallons per horsepower hour. This isn't because the conversion is difficult (it isn't) but because



almost every engine's specific fuel consumption curve seems to understate the real- world, in-the-boat fuel consumption.

- In practice, I've found that almost all diesel engines consume approximately 0.274liters per kW/hr.
- For the 420 CX Yanmar, propeller output power at 2,300 RPM is 250 HP, so fuel consumption at this RPM (assuming the propeller is properly matched) is 220gms/kW, while at maximum 2,700 RPM fuel consumption is 230gms/kW. (The shape of the specific fuel consumption curve and its point of maximum and minimum consumption are usually quite accurate in service, just not the absolute consumption numbers indicated.)

Determining Optimum Cruising Speed

- So far, we've seen what the engine performance curves mean and that maximum oomph and fuel efficiency occur for this engine at between 2,000 and 2,100 RPM. Is this the proper cruising speed? Well, an argument can be made for this in terms of sheer efficiency, but it'd be a bit slow. In- stead, we can look at the performance curves to determine where the best compromise between efficiency and speed falls. In this case, 2,300 RPM looks like a good bet. At 2,300, torque is still high, specific fuel consumption is still low, and we're getting a reasonable 250 HP at the propeller. Low cruise, for quiet, efficiency, and maximum range would be around 2,000 RPM, and you'd only open her up to 2,700 from time to time to show off or outrun a storm.
- OTE: If you don't have any engine curves available, you can estimate that the propeller power at various RPMs as follows:
 - 90% of max RPM = about 68% of max rated engine power
 - 80% of max RPM = about 48%; 70% of max RPM = about 30%; 60% of max RPM = about 22%; 50% of max RPM = about 15%; 40% of max RPM = about 11%
- To determine the impact of adding a 9 kW high-efficiency BMG to the fuel consumption of the Yanmar 420 CX engine at cruising speed (2,300 RPM), we can follow these steps:

Diesel Engine Efficiency at Cruising Speed

- At 50% of maximum RPM, the engine is typically operating at a point of high thermal efficiency, near its sweet spot in the fuel map.
- Engines are often most fuel-efficient between 40–60% of their maximum RPM and load capacity.
- The increased load of a high power BMG improves the engine's brake-specific fuel consumption (BSFC) slightly, as diesel engines are generally more efficient under higher load conditions within their optimal range.
- BMG Efficiency: Running the BMG at full load typically results in its peak efficiency (85%), minimizing losses in converting mechanical power to electrical energy.
- Engine Efficiency Impact: Adding the BMG load increases the engine's total load, potentially pushing it closer to its optimal operating point, which can slightly improve overall fuel efficiency.

Impact of BMG

- Additional fuel consumption = $53.70 - 50.96 = 2.74$ liters/hour.
- Percentage increase = $(2.74 / 50.96) \times 100 \approx 5.4\%$.
- The BMG load at maximum output has a minimal adverse impact on overall system efficiency at cruising speeds.
- In some cases, adding the BMG load improves the fuel efficiency of the engine by moving it closer to its optimal operating range.
- Adding a 9 kW BMG load to the Yanmar 420 CX engine at cruising speed increases fuel consumption by approximately 2.74 liters/hour or about 5.4%.
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