An Introduction to Electrical System Design for Cruising Vessels

No matter if it's a new boat or an extensive electrical system refit, finding the right electrical system configuration can be a daunting task.

In Years Past

Going back say 30 years, a cruising vessel that had live aboard capability most likely had a dual battery system that catered for pumps and lights. Refrigeration was handled by an engine driven compressor that required running twice a day for a couple of hours each time to pull down holding plates - at the same time charging fairly low capacity batteries.

The vessel galley was a simple affair with no appliances to speak of. Even the kitchen sink had a manual foot pump for salt water and maybe one for fresh as well. The navigation electronics was limited to a depth sounder. On a sail boat, a wind vane steering system served as the "autopilot" to hold the vessel on the same relative wind angle. So even under way, the total electrical demand on the vessel was minimal.

Such a system is perfect for those who demand simplicity and like a camping out lifestyle. It's interesting though that such a system is not necessarily "cheap". For example a quality engine drive holding plate fridge/freezer system could easily exceed $8,000.

A Modern Vessel System

The electrical demand on todays vessel is considerably higher than in the past. For cruising sail boats that are under way, the extensive navigation electronics package, autopilot and standing house loads demand a considerable amount of energy.

Appliances that require 230 volt AC power utilise an inverter to convert battery voltage to 230 volt AC. The vessel is equipped with an AC power distribution system that from a use point of view is similiar to the common household. Typical appliances might include air conditioning, a toaster, convection microwave oven, induction cook top and electric kettle.

Refrigeration systems are better handled by battery sourced DC compressors. They do a better job at keeping near constant box temperatures over the 24 hour period. When moored at a marina, the vessel battery charger will maintain the battery charge which means there is no need to run an engine.

The 12 or 24 volt DC system directly supports all pumps, lighting, sanitation, desalination, navigation electronics and autopilot loads. The DC house battery system works in close concert with the start battery and engine alternator which is typically the main vessel charging source.

Where higher and continuous AC loads like air conditioning are required, an engine powered generator set might be employed to run the higher AC loads as required and to facilitate battery charging. However it's not unreasonable to power a small cabin air conditioner from the house battery through an inverter.

It is clear then that the house battery plays a very important role in modern electrical systems. It need to be large enough to carry the vessel loads whenever power sources are insufficient to carry them directly. In conjunction with the charging system, a general objective is to run the engine or generator for a minimal amount of time. The battery technology is therefore a significant factor.

Renewable energy is very effective as a energy source that can minimise or eliminate running an engine. It basically boils down to having enough surface area available to employ the panels. For example a house boat or sedan cruiser has a much better chance of being solar sufficient by comparison to a sailing boat or fly-bridge cruiser. None the less, the more solar the better.

The following discussion presents an overview of the design process employed by Outback Marine. An essential input to this process is detail understanding of the equipment to be electrically powered and the intended mode of vessel operation.

Electrical System Overview

A vessel electrical system can be as simple as a single battery system used on an outboard powered trailer boat. A complex system will have separate house and starting battery banks with sophisticated AC and DC power distribution arrangements and system monitoring.

The block diagram below shows the functional components of an electrical system typical for a cruising vessel. It is equipped with house and start batteries, AC generator, solar, wind, inverter charger, engine charging, and so on.

DC and AC power sources provide the energy to run the vessel. Batteries provide an energy buffer to supply power when there is not enough instant power available from AD and DC sources.

DC (direct current) power is a low voltage form of power that is directly compatible with battery systems. AC (alternating current) power is the same as that found in industry and households. Power conversion equipment is used to convert power from one form to another.

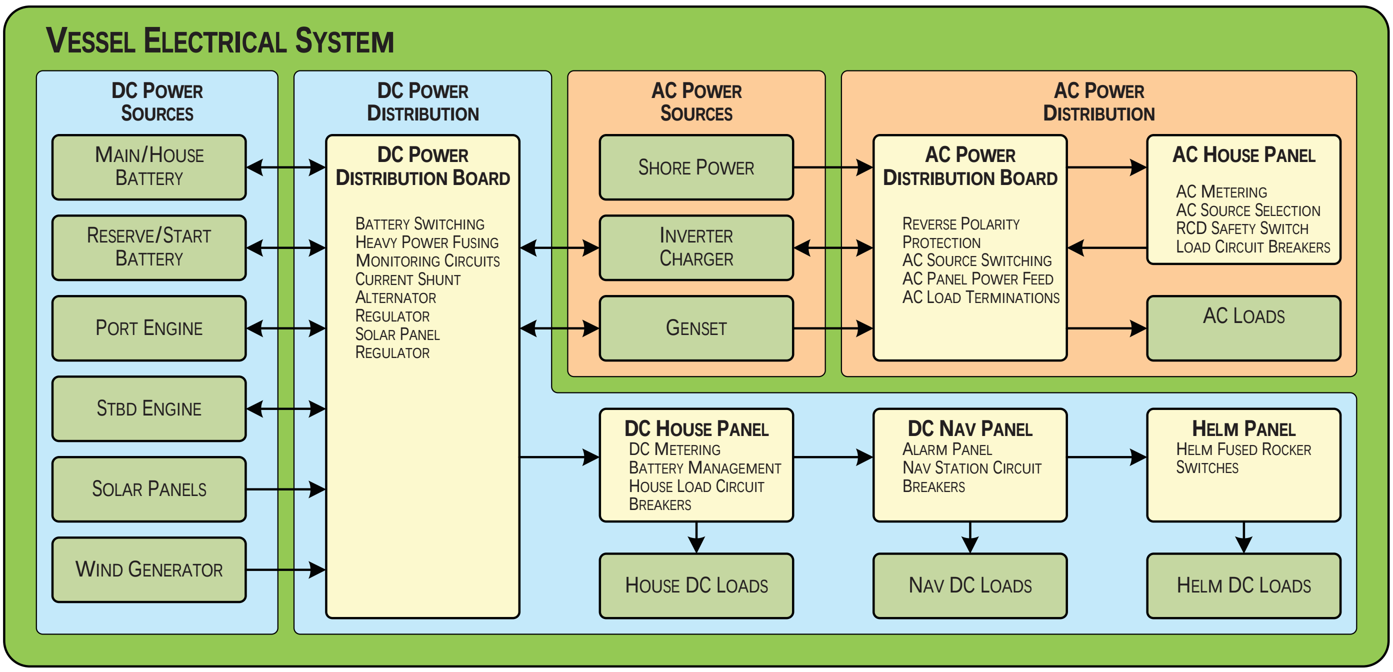
A power distribution network connects the power sources to the power consumers. Distribution boards and electrical panels use circuit breakers, switches and fuses to control devices and protect the individual circuits against overload conditions.

The distribution boards and panels are located in areas that are accessible for switching and central from a wiring point of view. A reasonable compromise is usually reached.

An electrical system design will require an understanding of the electrical consumers on the vessel (that is equipment and appliances) and the purpose or deployment of the vessel. A system specification that details the power generation, battery requirements and power distribution equipment can then be produced in order to meet the load requirements and operational expectations of the vessel.

The equipment setup is influenced by the project design objectives which in turn drives the cost of the implementation. Design objectives will consider:

- A safe implementation that meets relevant equipment and installation standards
- Reliability that's in line with the intended vessel operation
- Reduction of engine run time in support of faster battery charging
- Deployment of solar and wind energy to reduce engine run time
- Selection of effective battery capacity and technology
- Appropriate system monitoring and control
- A higher level of energy efficiency for deployed consumer devices



Power Distribution

Power distribution is the mechanism to safely interconnect and control vessel batteries, power generation and power conversion equipment to vessel loads.

DC Distribution Board - This is the central wiring hub for all heavy power devices including the batteries, engines, inverter, battery charger, windlass and electrical panels.

A house battery supplies power to all loads except the engines which have a dedicated start battery. All battery connections are made through isolation switches which provide the means to turn off the batteries in case of a fire or other electrical emergency situation.

A single ground bus-bar provides a common grounding point for all heavy negative cables and battery negatives. One or more positive bus-bars have individual fuses for each positive circuit to provide over-current protection.

Engines and their start battery are usually connected to a dedicated bus-bar that connects to the house battery via a cross charge device. This serves to charge the house battery from the engines when running while making sure that the start battery can't be discharged by house loads.

Electrical Panels - provide sub circuit power distribution. Although a single electrical panel can be employed, more often there are multiple electrical panels so that control of the loads can be placed at a location that is more convenient for operation. In either case, panel functionality can be grouped. DC and AC panels are always separate.

DC House Panel - Circuit breakers on this panel (with the exception of security and bilge pumps) are typically on or off according to whether you are on the boat or not. It services all "house" functions.

DC Navigation Panel - Often located within convenient reach of the helm, this panel controls navigation lights, vessel instruments, communications and other gear that is associated with vessel navigation and operation.

DC Helm Panel - While helming the vessel, this panel allows switching of loads directly associated with driving the boat. Items like the horn, anchor control, trim tabs and cockpit lights would be found here.

AC House Panel - Like the DC house panel, this panel distributes power to the AC loads on the vessel. Here we would find circuit breakers for the battery charger, air conditioning, hot water, appliances and general power outlets.

An electrical system cabinet on a Lightwave 38 sailing catamaran houses the electrical panels, DCD Board, Inverter Charger and Solar Regulator. The Lithium battery is under the settee to the right.

The DC distribution board highlights the use of bus bars and terminal fuses to provide an industrial strength solution for positive and negative cable termination. Remote operable battery switches also have manual capability.

Power Generation

DC and AC power generation equipment is the source for all power consumed on the vessel. The equipment listed below highlights the diversity of generation methods. In practice only a subset of these methods will be employed.

Main Engine Alternator - Engines will always have an alternator for charging the start battery. For faster and more reliable charging, the alternator is upgraded to a higher power rating and utilized to also charge the house battery bank.

Alternator Regulator - A special alternator regulator is used to ensure that the correct and safe charge voltage is employed for all conditions and to that the alternator does not overheat.

Solar Panels - can significantly reduce or eliminate engine run time if the panels are appropriately sized to vessel loads and the vessel has effective reserve battery capacity. To be effective, solar panels are mounted in a clear unshaded area.

Solar Panel Regulator - is used to get the most out of the solar panel array and to ensure that the batteries are being charged correctly.

Wind Generator - Sailboats can effectively use wind generation when under way. They only start to be effective in wind speeds above 12 knots which means they are not that effective at anchorage in the lee of an island that blocks the wind.

Tow Generator - Using similar technology to a wind generator, a tow generator uses the energy flow of water over a propeller to turn a permanent magnet alternator. They can only be used when the vessel is under way.

Shore Power - Single phase 240 volt/15 amp power is available at most private and public dock facilities. It is generally used to charge batteries and run appliances while at the dock. It requires special on-board power distribution equipment to comply with Australian standards.

AC Generator - When higher AC loads (such as air conditioning) is specified, an on-board generator is generally required. They are often used in conjunction with an inverter charger to allow battery charging when the generator is running and to provide AC power when the generator is stopped. We know of a 15 meter power vessel where a generator is run once every 3 days for only 3 .5 hours to supply through an inverter/charger.

DC Generator - This is a smaller dedicated engine that powers an alternator to directly charge the batteries. Like the main engine alternator, it will also require a special external regulator. Smaller AC generators with inverter/charger are more common.

Micro Nuclear - Be the envy of all your fellow cruisers. Micro nuclear fuel cells are the ultimate in providing silent power to your vessel for both above and under water cruising.

Replacing the standard engine alternator with a high output model can significantly reduce engine run time for battery charging at anchor. This unit is fitted with a high power capacity serpentine belt conversion kit.

Solar panels are an effective means of energy generation for a cruising vessel. In this case, 1000 watts of solar has enough charging capacity to meet the daily electrical load including refrigeration and hot water heating.

Power Conversion

This category of equipment converts power from one form to another.

Mains Battery Charger - This device is powered by 240 volt AC. It converts the AC power to DC power that is correct for charging the house battery. House batteries require special multi-stage charging and temperature compensation for safe and reliable operation.

Inverter - An inverter provides 240 volt AC power from the batteries. As the energy is sourced by the battery, a generator or shore power is not required.

Inverter Charger - This device combines the functionality of a battery charger and an inverter. It is more cost effective than individual components.

DC to DC Battery Charger - In many cases, a secondary battery requires charging from a remotely located primary battery/alternator source. The DC to DC charger compensates for the voltage drop in the interconnecting cables.

DC to DC Converter - Most often it is used to convert one voltage level to another. As an example a 24 volt house system will use one to provide power to 12 volt loads.

Isolation Transformers - Isolation transformers provide ultimate safety and electrolysis protection for shore-power systems. They are considered essential for aluminum boats and recommended for any metal boat.

An inverter charger provides AC power when the generator is not running or when shore power is unavailable. The integral battery charger and adjacent solar panel regulator take care of battery charging.

System Monitoring

This class of electrical system requires a monitoring system to provide the information required to operate the system in a safe and effective manner. The system should warn of potentially dangerous situations if any operating parameters are in an unsafe zone.

Battery Monitor - In addition to indicating volts and amps, a battery monitor can calculate the remaining battery capacity by counting the amps in and out of the battery over time. In this role it acts as a fuel gauge. It has the ability to monitor critical parameters and provide an alert if certain parameters are operating outside of their programmed set points.

Battery Management System (BMS) - Having all of the battery monitor functions, the BMS adds control functionality. Although this device is essential for Lithium batteries, it can also be used to advantage for AGM and other battery technologies.

In addition to providing an alert for abnormal conditions, the BMS can also control battery switches and other devices.

Internet Gateway - Newer devices offer a communication path to the Internet so that all information from the vessel can be stored and shown in a graphical representation. Any alarm condition can send an email to one or more nominated addresses. So next time the power cord at the dock is kicked out, an email will alert you.

A lithium battery management and control system panel monitors the key parameters of the vessel battery system and provides remote control of the battery switches and charge system devices.

Energy Storage

Continuous power requires the storage of energy in a battery bank. The propulsion engine requires power from the start battery. A house battery stores the energy that is used by general vessel loads.

The battery stores energy from the engines charging device whenever the engine is running. A smaller propulsion engine can effectively supply power for the vessel by charging the batteries while under way and at anchor. The charge time can be shortened by increasing the charge capacity of the source provided the battery charge acceptance rate is in line with the available charging amps.

When solar power is used, the battery supplies power when the sun is not shining. Again it is important to match the battery capacity, charge acceptance rate, available charge current and vessel loads.

Start Batteries - are generally designed to provide higher current levels for short periods of time. They are most often maintenance free AGM technology and are selected according to the cranking requirements of the engine. Certain deep cycle AGM batteries can serve both cranking and reserve duties to act as a backup in case the house battery is not available.

House Batteries - As the name implies, the house battery provides the power for all “household” functions. House batteries are available in a range of technologies. The capacity of the house battery is determined by factors such as technology, weight, number of life cycles, charge characteristics, discharge characteristics and cost. A house battery should also act as a backup for the cranking battery.

AGM Batteries - Known as Absorbed Glass Mat batteries, these are a lead-acid technology that is maintenance free. They are suitable for house and starting applications. AGM batteries are resilient to full discharges however their cycle life will be significantly shortened.

Lithium Ion Batteries - Specifically Lithium Iron Phosphate batteries (LiFeP04) have significant advantages over their lead-acid counterparts.

- Do not emit explosive gas when charging
- High charge acceptance rate
- No need for periodic full charging
- Do not require absorb charging
- Very high cycle life
- Low effective weight and volume

Lithium batteries require proper battery management to safeguard their operation from premature failure.

This installation shows a 24 volt 360 AH (8.5 Kwh) lithium battery installed in the same cabinet as other active electrical equipment. This installation is safe as lithium batteries to not produce a flammable gas when charging.

Lithium Iron Phosphate batteries have become the battery of choice for sailing catamaran owners who desire light weight and flexible charging performance. This 12 volt 540 AH battery is shown without top cover.

A System Design Approach

A new design starts with an interview process that examines the owners use and operational expectations of the vessel. Clear objectives are established and budget trade-offs are discussed. With a general arrangement plan of the vessel and details of existing or planned propulsion and consumer equipment provisions, a system design document can be created.

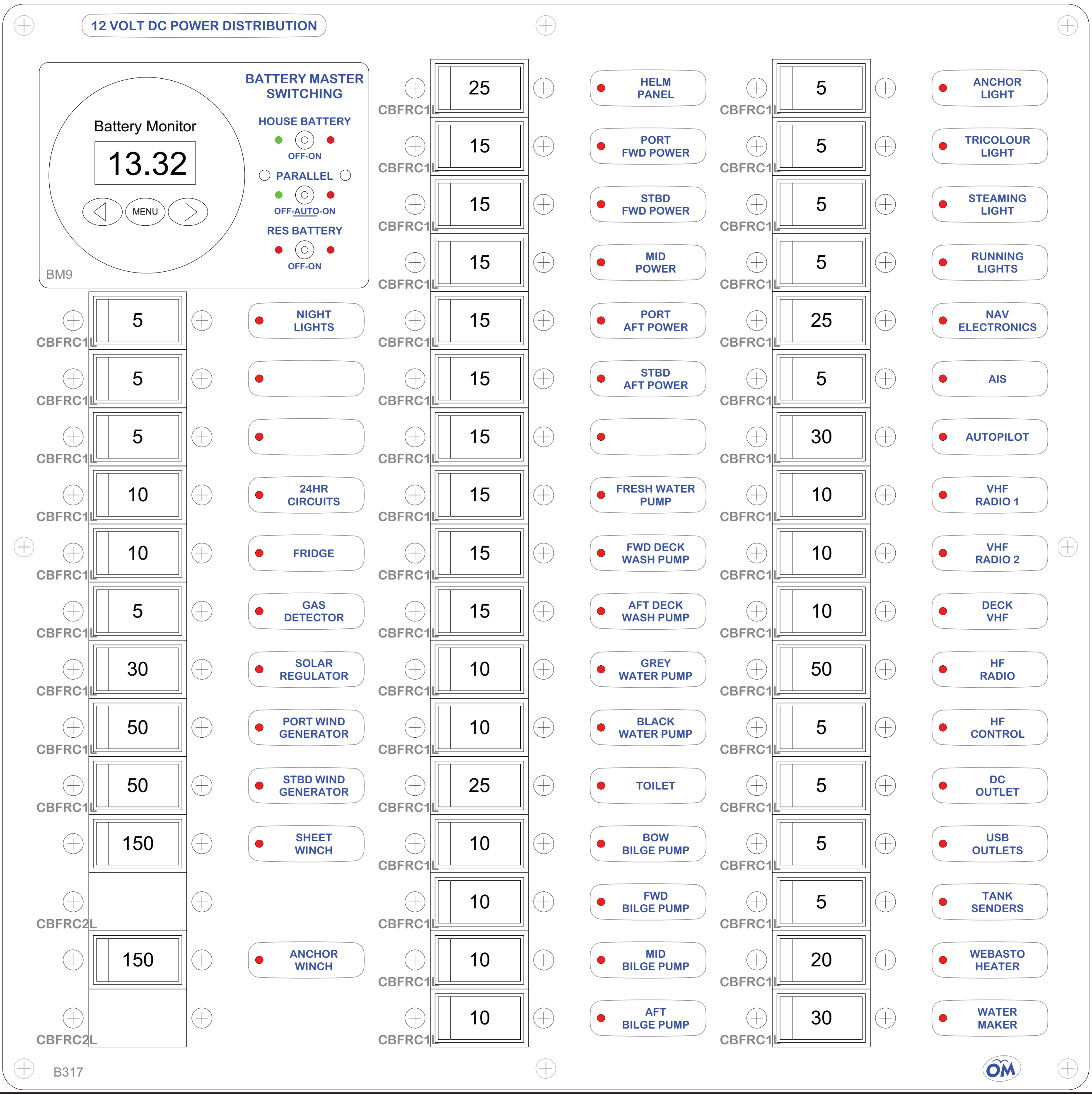
- It identifies each significant component of the electrical system required to meet the overall objective
- Shows the general wiring arrangement of each major circuit

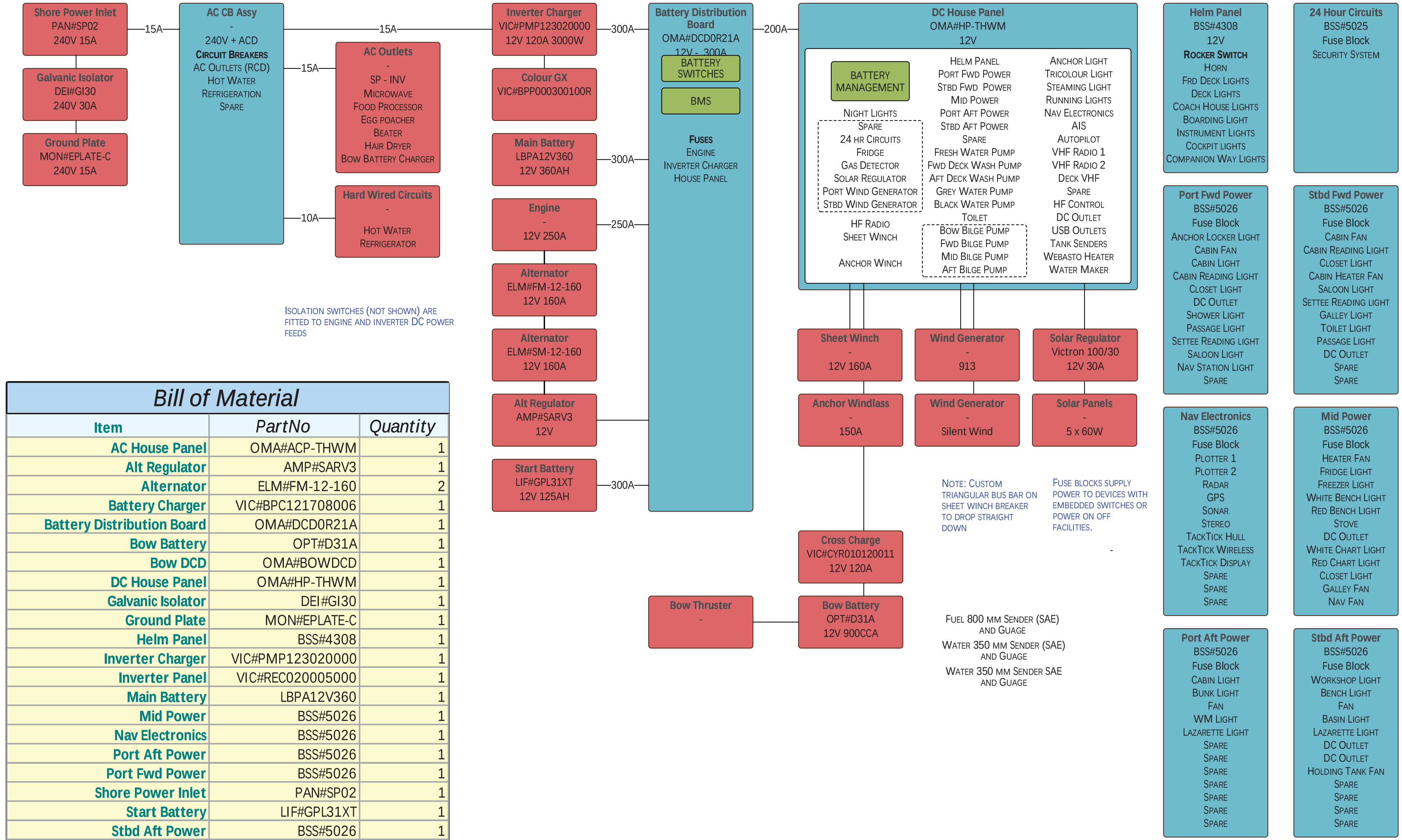
Once the system design document has undergone the review process and circuits are finalized, the exact layout of the electrical panels is created. The custom panels exactly match the vessel system.

- Identifies each electrical circuit required on the main circuit breaker panel, sub panels and fuse blocks
- Produces a detail bill of materials that is used for project costing.

Once the draft document has been reviewed by the owner/builder, electrical panel layouts are created and presented for review. Once signed off, a detail quotation for supply of equipment is generated.

The design is matched to the operational requirements and owner performance objectives for the vessel. The documentation is generally sufficient for an experienced marine electrician to undertake installation.





Bill of Material

Item	PartNo	Quantity
AC House Panel	OMA#ACP-THWM	1
Alt Regulator	AMP#SARV3	1
Alternator	ELM#FM-12-160	2
Battery Charger	VIC#BPC121708006	1
Battery Distribution Board	OMA#DCD0R21A	1
Bow Battery	OPT#D31A	1
Bow DCD	OMA#BOWDCD	1
DC House Panel	OMA#HP-THWM	1
Galvanic Isolator	DEI#GI30	1
Ground Plate	MON#EPLATE-C	1
Helm Panel	BSS#4308	1
Inverter Charger	VIC#PMP123020000	1
Inverter Panel	VIC#REC020005000	1
Main Battery	LBPA12V360	1
Mid Power	BSS#5026	1
Nav Electronics	BSS#5026	1
Port Aft Power	BSS#5026	1
Port Fwd Power	BSS#5026	1
Shore Power Inlet	PAN#SP02	1
Start Battery	LIF#GPL31XT	1
Stbd Aft Power	BSS#5026	1
Stbd Fwd Power	BSS#5026	1

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