THE BALANCED ENERGY SYSTEM 8/14/2009

As boaters we all know what it is like to try and live on 12 volts and all the problems that are related to it. How many times have you run your fridge until it quits due to low voltage? Run lights and entertainment systems until they will not function properly. Tried to charge your batteries not knowing how long to run your engine for or how much charge is going into the system. Went to start the engine and the battery was dead. Tried fixes like adding more batteries and then finding out that you are in the same situation a few weeks later.
This is the reason that we need to have a "Balanced Energy System". Whatever amount of energy we use we have to replace. Therefore we have to have a means to monitor the amount of energy we use and be able to effectively and efficiently replace this energy knowing the rate of charge and how long it takes. Therefore we have to design a "Balanced Energy System". How we do that? Well let's break it into several steps and develop an understanding of what is required to achieve these steps.

1 We have to calculate our daily power requirement in Amp/Hrs

2. The next step would be to determine a battery bank to provide the required energy.

3. Now we need a means to charge this battery bank.

4. We will require a way to monitor the battery bank. How much energy is consumed under use and how much energy is going back into the battery during charging cycle.

5 The system will require maintenance and upkeep.

Step one

We need to determine our daily power requirements in amp/hours.
An amp/hour is 1 amp of current being consumed for 1 hour. Therefore if you had a 5 amp load on for 2 hours you would use 5amps x 2 hrs = 10 amp/hours.
Using Watts law we can find the amperage draw of a device if we know how many watts it is rated for. Amps = watts divided by volts. Ex. A 50 watt light bulb on a 12 volt supply. Amps = 50 watts divided by 12 volts
= 4.16 amps

Following is and example of calculating "Daily Power Requirements" for a 24 hour period

Device	Rating	X	Hrs of use	=	Total load in 24 hrs.
6 -25watt lights	2.1 amps each		2 hrs. each		25.2
1- 50 watt Fridge	4.2 amps		12 hrs		50.4
1- Laptop computer	2.5 amps		2 hrs		05.0

1- am/fm radio	1.5 amps	10	15.0
1- 300 watt inverter	25 amps	1 hrs	25.0
		TOTAL AMP/HR	120.6

Note: Items of high amperage draws with occasional and short term use can normally be ignored since they have little effect on the overall picture. EX. Anchor windlass.

STEP 2

Determine the battery bank size to supply the required load for a 24 hour period.
Rule of thumb is that the battery bank should be 3 to 4 times the daily requirements in amp/hrs.
Therefore in the above example we would need a battery bank that is from 360 to 480 amp/hr. This could be achieved by using two "8Ds"batteries (240 amp hr. ea.) providing 480 amp/hr. total, or four 6 volt batteries (220 amp/hr. ea) in series parallel providing 440 amp hr. total. Now we have to decide on what type of batteries and where they will be located. Factors such as ongoing maintenance, ventilation, physical location, battery size and installation have to be considered.
In order to make a proper chose it requires some basic knowledge of batteries. Although batteries appear to be so simple the installation and use of them becomes complex and creates many problems not understood by most boaters.

How Batteries Work

Batteries consist of individual 2 volt cells connected in series to make up various sizes, normally 6 and 12 volt batteries. Each cell consists of Positive plates (Lead Dioxide) and Negative plates (Sponge Lead) with a porous separator between them and immersed in sulfuric acid (Electrolyte). During discharge, the chemical reaction of the electrolyte reacting with the lead plates forms lead sulfate on the plates. This chemical reaction creates the electrical current when connected to a load. During this process the concentration of sulfuric acid in the solution is reduced and water increased lowering specific gravity and voltage drops. When charging the opposite takes place. The strength of the electrolyte is restored as the lead sulfate is converted back to sulfuric acid and as specific gravity raises voltage increases.

Battery Facts

- Battery discharge normally should not exceed 50% of rated amp/hrs.
- Only 0.4 volts difference between a fully charged 12.6volts and a 50% 12.2 volts discharged battery.
- Only 0.9 volts difference between full charge 12.6volts and full discharge 11.7
- Battery has to be at rest 24 hours (no charge or discharge) before accurate specific gravity can be measured.
- Batteries for house systems are rated in "life cycles" for endurance. One life cycle is to discharge the battery to 50% and charge back to 100%.
- Discharging below 50% greatly reduces the life cycles.
- Hydrogen gas is explosive.

Battery problems

- Deep discharge and not getting fully charged. Sulfate builds up on plates and does not get converted back to sulfuric acid reducing the reactive area of the

plates. EX. A 100 amp/hr. rated battery can be de-rated by 25% now it is a 75 amp/hr. battery. Number 1 cause of battery failure
- Continual discharge below 80%
- Overcharged by a defective or cheap charger at over 13.8 volts upon completion of charge. Causes gassing, lose of water. Galvanic activity in batteries attacking positive plates. Second major cause of battery failure.
- Undercharging of battery (never above 13.8 volts) Plates get sulfated and lose of capacity.
- Overheating of battery due to high voltage. Causes plates to warp and short out. Do not charge with battery temp above 120oF.
- Dirty batteries cause self discharge.

Battery Types

A/ Deep Cycle Wet Cell

- These are an excellent choice for a house bank. The plates are thick with dense active material, heavy plate separators and tough construction. They are designed to tolerate repeated deep discharges. Need to be installed in a vented area.
- They require monthly maintenance, topping up with water and keeping clean.
- Provide a long life if maintained, up to 2500 life cycles at 50% discharge

B/ Golf Cart Batteries

- Not a true deep cycle but can supply moderate currents for sustained periods. Need to be installed in a vented area. Good for house banks
- Come in 6 volt only so have to be connected in series for 12 volts
- Require continual maintenance as above.
- Great value for the money.

C/ Gel Cell Batteries

- Ideal for locations that do not have ventilation or difficult to perform maintenance. Good for house banks.
- These batteries have different charge characteristics than wet cell and should not be mixed with them without special installation procedures. Very intolerant of over voltage charge conditions.
- Accept charge faster than a wet cell due to many lighter plates immersed in gel. Recommended by inverter companies.
- More expensive and less life cycles that a wet cell. 800 to 1000 life cycles at 50%.

D/Absorbed Glass Mat (AGM)

- Excellent batteries for house and inverter banks
- **Some manufactures have batteries that take up 40 % less space than a wet cell of the same amp/hr. rating**
- **25% less weight than an equivalent wet cell**
- **High discharge and recharge rates**
- **Can be installed in locations that you cannot use wet cells**
- They have few charging limitations and can be discharged 30% lower than gel and wet cells. They recharge 20% faster than gel cells.
- Expensive but good value for specific applications.

E/ Starter Batteries

- Starter batteries are designed to output large amounts of current to start engines or run devices such as bow thrusters. They are rated in CCA (cold cranking amps) they are not suitable to use as a house bank.
- They can provide high current for short durations due to the fact that they have many thin plates providing more reactive area.
- The correct battery has to be selected based on the size of the engine and the starter current required.

Note: the above battery info is in general and the specific manufacture should be contacted for correct charging characteristics and use.

Step 3

Consider Battery Charging Methods

Proper charging of batteries is important. High quality charging devices will use smart charging steps as follow:

Bulk cycle

- Charge Wet cell batteries at 25% of the rated capacity in amp/hrs at up to 14.4 volts until 75% charged
- Charge gel cells at 50% of amp/hrs at 13.8 volts

Absorption cycle

- Voltage is held constant at less than 14.4 volts and battery absorbs current at a lower rate until near full charge.

Float cycle

- The final stage should maintain the battery at a 13.2 volt level

Equalization

- This is a manual operation to be performed when the battery is fully charged and should be done after heavy use. Approximately every 60 days.
- A constant current of 4% of rated capacity is applied until voltage rises to 16.2 volts.
- This will reconvert the sulfate off the battery plates back to sulfuric acid.

Batteries can be charged by several different methods such as alternators, battery chargers, solar and wind. We will look at the first two.

A/ Stock Alternators

- Most gas engines are equipped with a stock alternator usually rated at 50 to 65 amps. These alternators are designed to charge a starting battery and keep up the electrics involved with the operation of the engine. They will output high current for a short period of time and then the current drops off. They are not suitable for charging of large deep cycle banks. They have internal regulators which cannot be adjusted.

B/ High Capacity Alternators

- These alternators are rated at 100 to 150 amps in small case and up to 300 amps in large case. They designed to output high current at low RPMs and are meant to charge large deep cycle banks. They have large internal diodes and

heatsinks to withstand heavy load. They usually have external voltage regulators. For boaters who have to depend on the alternator as the main charging source then three stage smart regulators are available.

- The alternator should be rated at 25 to 40% of the batteries capacity.
- *Note: an alternator output is rated with the rotor spinning at 10,000 RPM which you will not see on the boat; therefore a 130 amp alternator may only output 90 amps with your engine running at 3000 RPM.*

C/ Battery chargers

A quality battery charger is an absolute necessity with a large battery bank. The chargers available today far outperform the units built in the past. A good charger will restore the battery to full capacity and maintain it in a fully charged state with out overcharging. A smart charger should be rated at 15 to 20% of the amp/hr capacity of the bank.
Features we find on battery chargers now are"

- Four step regulation Bulk, absorption, float and equalization
- Battery temp sensors
- Ability to charge different types of banks at the same time EX wet cell, gel cell and AGM at the same time
- Remote displays
- NMEA data outputs (a whole topic of it own)
- 120/240 ac inputs 50 or 60 cycle.

E/ Charging multiple battery banks

Rule of thumb: Charge in parallel and discharge in isolation
This can be achieved in various ways.
Isolators: An isolator allows single of multiple alternators to provide charge to several battery banks with the use of large diodes that allow current to flow in one direction only. The isolator has to be rated for current flow greater than the current output of the largest alternator. They are simple and effective. They work well for alternators that have external regulators and sense wires. The down fall of isolators is that you lose 0.7 volts across the diode. Therefore if you have an alternator that has no external sense then the voltage will be too low at the battery.
ACR, s (Automatic Charge Relays)
There are many different types out on the market now. Basically they have circuitry which will sense a battery voltage. As soon as a charge is on the system ex. 13.6 volts then the circuit will close a solenoid and the battery banks would be combined charging all batteries. As soon as the voltage drops down to 12.8 volts then the circuit would open the solenoid isolating the house batteries12/11/2010 from the starter battery.
These work well for alternators with internal regulators as there are no voltage drops.

Step 4

Once we have decided on a system we have to monitor what is happening to the system. Without a monitoring system it is like driving a car without a gas gauge.
A good monitoring system will be programmed for the size of the bank and provide the following information:

- Voltage - The voltage level of the battery at discharge

- The voltage level of the battery during charge process

- Amps
  - The amps being drawn will be shown as a negative value. This allows you to determine the individual loads on the boat and the current draw of each one.
  - During charge process shows the amps value going back into the battery
  - During charge process you can determine how much current your alternator or charger is putting back into the battery.
- Amp/hrs
  - The unit is programmed for the size of the bank in Amp/hrs. During discharge it will show the accumulation of amp/hrs. And give a warning when the 50% discharge level is achieved.
  - During the charge process the unit counts down the amp/hrs as the battery absorbs the charge. Ex. If you used -125 amp/hrs then it counts down -124,-123,-122 until charge completion.
- Time Remaining
  - The unit can be set to look at a window of time from 5 to 16 minutes. It then calculate the average amps used during this period of time and then determines how many hours you can use the battery bank at that specific charge rate before it requires charging.

Note: Monitoring equipment is an absolute must to get ultimate use and longevity out of your battery bank and be knowledgeable of your system performance.

Step 5

Proper installation and maintenance is essential for maximum performance.

Installation

- Batteries have to be installed in a secure location in battery boxes that can contain acid in event of a failure. The location has to be accessible to check water level in the cells if a wet cell battery.
- Proper cable size and battery connections are required to minimize voltage drops and handle high amperage. Normally 2/0 for most installations
- Require fusing and battery switches

Maintenance

- Wet cell batteries should be checked on a monthly basis to ensure electrolyte levels are maintained. NOTE: Use only distilled water to top up. Since a battery is a chemical process we do not want other chemicals in the water.
- Keep batteries clean to prevent self discharge.
- Before winter storage, fully charge the batteries and equalize wet cell batteries.

Conclusion: Following all the steps above to install a "Balance Energy System" will give you a secure and dependable system that will enhance your boating pleasures.