Electricity – The Basics

This document will work through some of the basic principles of electricity and circuits. While many of us are already aware of this, it is always good to refresh our knowledge.

There are three key measures used to describe electricity in a circuit – Voltage, Current and Resistance. Every electrical circuit will have these three elements which can be measured. Figure 1 below shows the relationship between these three elements.

Voltage is measured in Volts (V) and can be described as the electromotive force or pressure which pushes electrons through a circuit. In the image to the right this is the orange dude applying force by pushing our green electron. The higher the voltage, the higher the pressure.

Current is measured in Amps (A) and can be described as the rate of flow of electrons past a fixed point in the circuit. A current of 1 amp means that 6.24 quintillion electrons (that's 6.24 billion billion) are moving past a given point every 1 second.

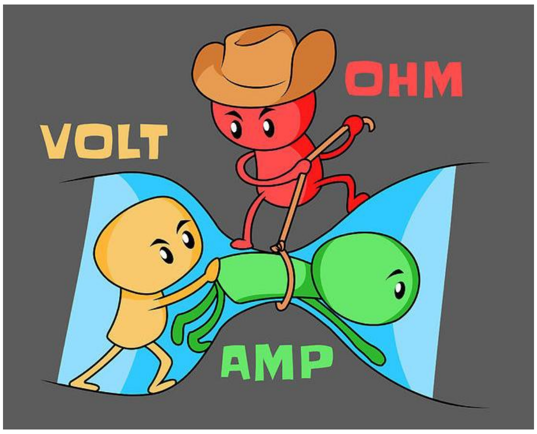

Fig. 1

Resistance is measured in Ohms (Ω) and can be described as the opposition to current flow in a circuit. The cowboy in the picture is using his lasso to try and stop the green electron flowing through the system.

Power

Power is measured in Watts (W) and can be described as the rate at which energy flows through a circuit. Power is what does the work, like creating motion, light or heat. Unlike the previous 3 elements which can be measured directly, power must be calculated by multiplying Voltage and Current together. This is why, for example, light globes are rated in Watts – this rating tells you how much power they will consume and can be used to compare with other globes even if they operate at different voltages.

The formula to calculate Power is:

Power (Watts) = Voltage (Volts) x Current (Amps), or **P=VI**

Let's look at two 240W electric motors which are identical expect that one is designed for 12V and the other 24V. We know they both consume 240W and we know their voltage, so we can calculate their current consumption by transposing the P=VI formula to I=P÷V.

For the 12V motor: I = 240 ÷ 12 = 20A　　　For the 24V motor: I = 240 ÷ 24 = 10A

This shows that the current flow changes as the voltage changes - if the voltage doubles, the current is half as it still must equal 240W.

AC⚡DC

A great Australian rock band, but what does it mean? AC stands for Alternating Current and DC stands for Direct Current.

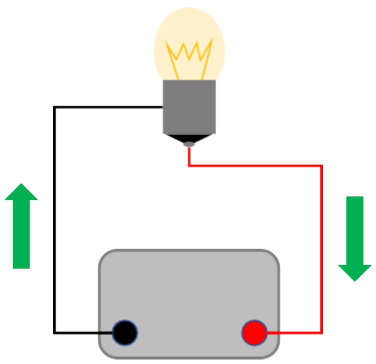

Fig. 2 – DC circuit

DC is easier to understand so let's start there. All batteries produce DC voltage. In a DC circuit (Figure 2) electrons actually flow through the wires from negative toward positive. This is because nature likes balance, and when a battery is charged the negative plates are loaded with electrons and the positive plates have none. As soon as you connect a circuit to a battery, the electrons start flowing from the negative post towards the positive post to try and balance. In Figure 2 the only way this can happen is through the light globe – a very thin wire which is a resistor. The thin wire becomes very hot and glows as the electrons flow through it to the positive side of the battery.

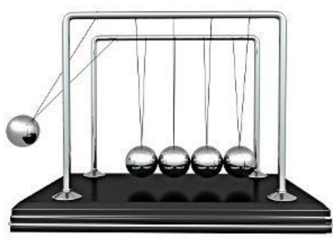

Fig. 3 – Newton's Cradle

AC is a little different. An easy way to explain AC is Newton's cradle shown in Figure 3. You lift the ball on one end and let it go, when the ball falls it strikes the next ball and the energy is passed through all of the balls to the ball on the other end which swings out as there is nothing stopping it. The motion is then reversed when the ball falls again. AC works in a similar way where each electron only moves a small amount in either direction but passes the energy on. The power point in your home delivers AC.

A disadvantage of DC voltage is the fact that the electrons need to move along the conductor (e.g. wire), and the resistance of the wire reduces the voltage as the wire gets longer. This is called voltage drop, and it means that you cannot transmit DC over a long distance efficiently. AC is much less affected by the wire resistance as the electrons stay within a small area – this means that you can transmit AC power over long distances more efficiently.

Parallel & Series

Parallel and series connections are discussed on a daily basis in our business. They have different characteristics and are used in battery installations to deliver either an increase in voltage, an increase in capacity, or both.

Series connection can also be described as a daisy chain (Figure 4). Batteries are connected in series when an increase in voltage is required, as the voltage of each battery is added together to determine the overall system voltage. The overall group capacity (Ah) remains constant. Each battery acts individually and is not affected by the other batteries. If one battery fails in a series connection, the chain is broken and the overall system is compromised.

When the battery group is being charged/discharged, the total current must flow through each battery.

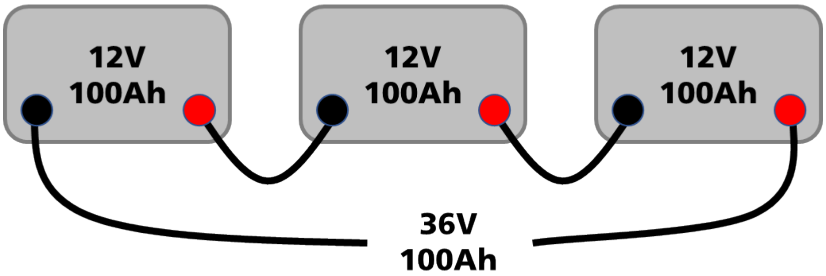

Fig. 4 - Series

Parallel connection is used when an increase in capacity is required without changing the voltage. Batteries connected in parallel act as one battery. As each battery is added, its capacity is added to the overall group capacity. A benefit of parallel connection is that the voltage of each battery will naturally balance with the others in the system. If a battery at 50% SoC is added in parallel to another battery at 100% SoC, current will flow from the 100% SoC battery to the other battery (i.e. charge it) until the OCV of both batteries is the same.

When the group is being charged or discharged, the total current flow is divided between each battery in the group. A parallel group will continue to automatically balance the voltage between each battery even when being charged and discharged. If one battery is 'weak', the other batteries in the group will deliver more current so that the OCV of each battery is the same.

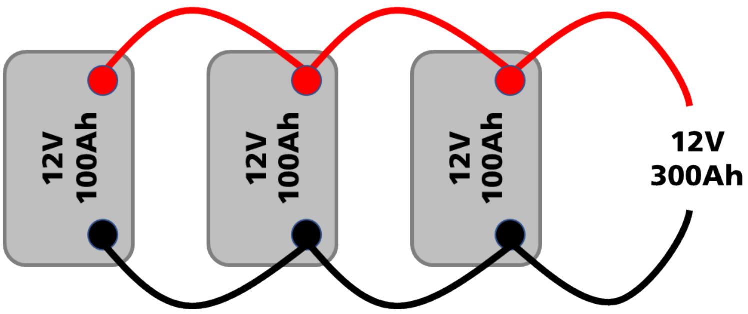

Fig. 5 - Parallel

Combinations

Batteries can be connected in a combination of series and parallel to provide an increase in voltage and capacity.

Figure 6 below shows two different ways to achieve a 36V 300Ah system using 9 x 12V 100Ah batteries. Although the system voltage and capacity are the same, one configuration is better than the other.

The system on the left has three groups connected in series which are then connected in parallel. This means that the voltage of each series string will balance with the others however the voltage of each battery is not balanced. You effectively have 9 individual batteries connected in series with this configuration.

The system on the right has three groups connected in parallel which are then connected in series. Although the three groups connected in series are not balanced with each other, the 3 batteries connected in parallel will balance. This is a better way of connecting batteries as you effectively have 3 batteries connected in series because the parallel groups act as one battery.

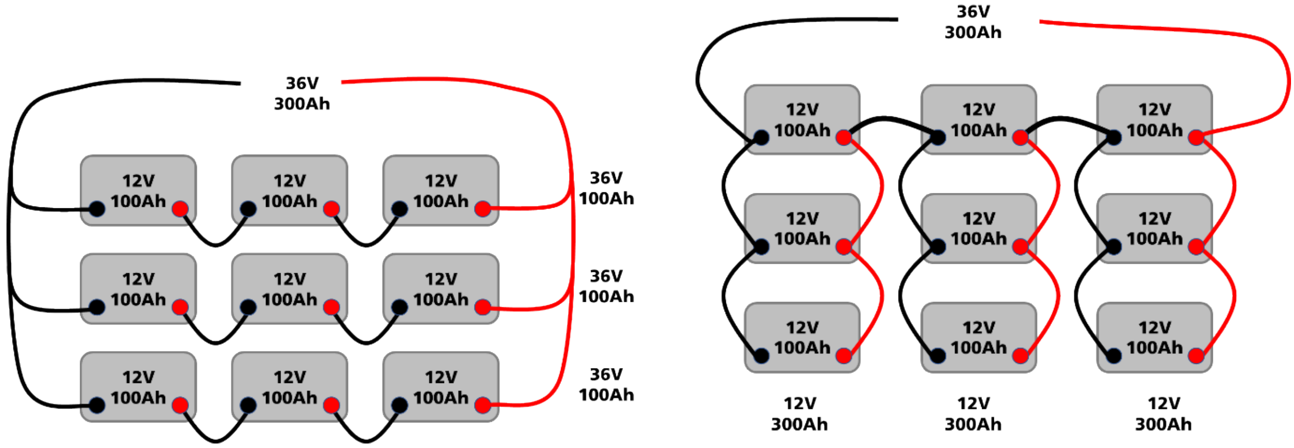

Fig. 6

Another application where parallel and series connections are used is lithium batteries like ALLiON & RELiON. Figure 7 show the internal configuration of an ALLiON 105Ah battery. There are 4 cell groups, each containing 4 cells connected in parallel. The 4 cell groups are then connected in series to increase the nominal voltage to 12.8V. By connecting the cells in parallel first, the BMS only needs to manage 4 cell groups rather than 16 individual cells.

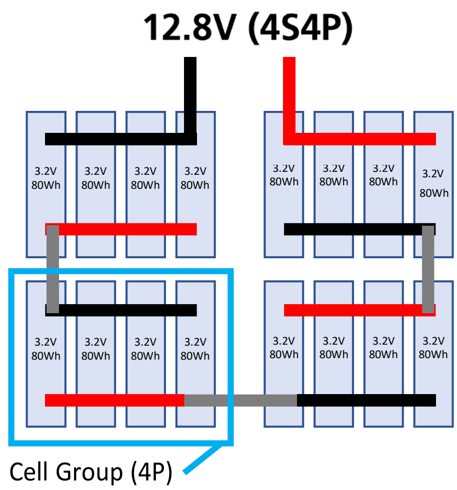

Fig. 7