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# Understanding Battery Voltage and Current

**Application Note**

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## Why does the voltage on a discharged battery measure the same as a fully charged battery, until loads are applied?

The simple answer to this might go as follows: A battery creates electrical power by converting energy from a chemical reaction into electrical energy. As this reaction slows down the battery voltage will drop. In a lead acid battery the electrolytes conductivity (how well electrical current can flow through it) changes. The same current may be available but the rate of the reaction decreases, causing a voltage drop.

It is interesting to note that a charged 12 volt lead acid battery at rest (not powering loads and unused for a least 3 hours) will read about 12.6 volts. Hook up a load and the voltage will drop to about 11.9 volts.

Another way of looking at this is to use an analogy of a water pump (a battery is an electric pump). The pressure in PSI a pump delivers is like a battery's voltage. The volume of water in gallons/minute (GPM) is like electrical current. Let's look at a 12 PSI pump with no loads (the pump is running but the outflow valve is turned off). The pump will run and the internal pressure of the pump will build up to some point higher than 12 PSI. Once the valve is opened and the water is free to flow into the loads, the pressure will drop to the rated output pressure of 12 PSI, but only if the load is not too big. If the pump is designed to maintain 12 PSI at 15 GPM, and a load demanding 20 GPM is connected, the pump will not be able to keep up and the pressure will get sucked down to some lower PSI. If the load is then reduced or removed, the pump will catch up and return to it's rated 12 PSI pressure. If the pump has an infinite source of water such as a lake or the water utility (this is like the grid, no battery) the pump will never run out of pressure, and as long as the pump is operated at or below it's 15GPM level it will hold 12 PSI.

However, a pump that is connected to a water tank with a finite capacity, will start to lose the ability to hold pressure as the level of water in the tank drops. Think of siphoning water from a bucket, as the level of the water drops the volume of water exiting the siphon slows down.

When the tank is full it is capable of feeding more "pressure" to the pump inlet due to gravity, and the pump always has enough water available to maintain its rated pressure and volume. However, if the water tank gets low the pump will not have enough water volume coming in to maintain 12 PSI at 15 GPM. If the loads are taken away from the pump by closing the valve on the outflow, even with low pressure in the tank the pump will eventually pump up to 12 PSI, it will just take it longer to get there. Then when the valve is opened the pump will sustain 12 PSI for a brief while, but since the tank is no longer feeding the pump as fast as needed the pressure will eventually drop. This analogy can be restated by replacing the pump with a battery, pressure with voltage, volume with amps, outflow valve with a switch, water with electricity, and the water tank with the battery electrolyte.

The level of the tank could be thought of as the rate of the reaction taking place in the electrolyte. When the battery is fully charged the electrolyte has an excess of reactions taking place to feed the battery terminals. This tapers of with time as the electrolyte is spent, so maintaining voltage becomes near impossible. With no loads, the spent electrolyte will be capable of producing near rated voltage but only after a period of time has elapsed for enough reactions to take place to bring the voltage back up. Hopefully this scenario will help make clear why a battery measured at rest can show near its rated voltage but will not run a load.

## Measuring battery condition with the battery at rest.

A good estimate of a battery's state of charge can be made by measuring the voltage across the battery terminals with the battery at rest (No energy input, no energy output) for at least three hours. These readings are best taken in the early morning, at or before sunrise, or in late evening. Take the reading while almost all loads are off and no charging sources are producing power. Connect a voltmeter across the positive and negative outputs of the battery or battery bank.

Table 1 will allow conversion of the readings obtained to an estimate of state of charge. The table is good for batteries at 77° F that have been at rest for 3 hours or more. If the batteries are at a lower temperature you can expect lower voltage readings.

**Table 1** Battery Voltage as a Function of Percent Charge

| Percent of Full Charge | 12 Volt DC System | 24 Volt DC System | 48 Volts DC System |
|---|---|---|---|
| 100% | 12.7 | 25.4 | 50.8 |
| 90% | 12.6 | 25.2 | 50.4 |
| 80% | 12.5 | 25 | 50 |
| 70% | 12.3 | 24.6 | 49.2 |
| 60% | 12.2 | 24.4 | 48.8 |
| 50% | 12.1 | 24.2 | 48.4 |
| 40% | 12.0 | 24 | 48 |
| 30% | 11.8 | 23.6 | 47.2 |
| 20% | 11.7 | 23.4 | 46.8 |
| 10% | 11.6 | 23.2 | 46.4 |
| 0% | <=11.6 | <=23.2 | <=46.4 |



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