COMPARING THE DIFFERENCES BETWEEN DEEP-CYCLE FLOODED AND DEEP-CYCLE VALVE-REGULATED LEAD-ACID BATTERIES FOR RENEWABLE ENERGY APPLICATIONS

Battery-based renewable energy systems vary greatly in size and design based on the purpose and location of the installation. In order to choose the right battery for your system it is important to understand the main differences between deep-cycle flooded, AGM and gel batteries. In this technical bulletin we will discuss the essential differences and benefits of these battery technologies with an emphasis on using deep-cycle batteries in renewable energy storage applications. We will describe how these technologies offered by Trojan differ, their operating principles, features and benefits, and factors that should be taken into account when selecting a battery for a renewable energy storage system.

Deep-cycle lead-acid batteries generally fall into two distinct categories; flooded (FLA) and valve-regulated lead-acid (VRLA), with the VRLA type further subdivided into two types, Absorbed Glass Mat (AGM) and Gel. These differences have evolved because no single design is suitable for all applications. One of the most frequently asked questions is how they differ and what their characteristics are.

Unlike many other battery applications, battery-based renewable energy applications are unique because the batteries in these systems can be discharged and charged in an unpredictable manner due to variations in sunshine, wind and hydro power. They are also subjected to seasonal variations that can result in the batteries having to operate in a partial state of charge for considerable lengths of time. These factors can cause the batteries to result in frequent deep discharges and lack of charge. Consequently, the most important requirement for batteries used in renewable energy systems is long cycle life. Deep-cycle lead-acid batteries are the best choice for renewable energy applications but it should be recognized that there are different types having strengths and weaknesses which influence their suitability and life.

Deep-Cycle Flooded Lead-Acid Batteries (FLA)

Deep-cycle flooded lead-acid batteries are the most popular type in use today for renewable energy systems. Although flooded batteries are available in flat and tubular plate versions this technical brief will concentrate on the flat plate type since this is the most widely used. The term "flooded" is used because this type of battery contains an excess of electrolyte fluid so that the plates are completely submerged. The electrolyte level should be above the tops of plates which serves as a reservoir to make sure that water loss during charging does not lower the level below the plate tops and cause damage.

Here are some of the advantages of using deep-cycle flooded batteries:

- **Lower cost than deep-cycle VRLA batteries.**
- **Longer deep cycle life than deep-cycle VRLA batteries.**
- **Can be maintained simply by addition of distilled water.**
- **High discharge rate capability.**
- **Perform better in hot climates. (>90 degrees F)**
- **More available worldwide.**
- **Perform better then deep-cycle VRLA batteries when regularly in a partial state of charge.**
- **Long, proven history of use.**

Some of the drawbacks of using deep-cycle flooded batteries are:

- **Periodic maintenance by adding distilled water is required.**
- **Can only be used in an upright position.**
- **Produce gas (oxygen and hydrogen) when charged.**
- **May emit acid spray if overcharged abusively.**
- **Require ventilation.**
- **Higher self-discharge rate than deep-cycle VRLA batteries.**
- **Cannot be shipped by air.**
- **Cannot be used in the immediate vicinity of electrical equipment or anything highly flammable.**

In summary, deep-cycle flooded lead-acid batteries are very versatile and should be the first choice for renewable energy systems where maintenance can be carried out and ventilation is available.

Deep-Cycle Valve-Regulated Lead-Acid Batteries (VRLA)

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Deep-cycle VRLA batteries were developed in the late 1960s to eliminate the need for water addition and to provide batteries that could be used in any position. They are designed so that oxygen evolved from the positive plates during charging can migrate to the negative plate where it is reduced to water. This process significantly reduces water loss. In actual practice this is not always the case because the oxygen reduction reaction is not 100% efficient and the surplus oxygen must be vented together with an equivalent amount of hydrogen. For this reason, VRLA batteries are fitted with a pressure vent that allows surplus gas to be vented when the internal gas pressure builds up. This is why they are called valve-regulated, not sealed batteries. Although gas evolution is considerably reduced it is not eliminated entirely and VRLA batteries can still lose water and become dry.

For this process to operate oxygen must be able to migrate from the positive to the negative plates. This can be accomplished in two ways which has led to the development of the two classes of VRLA batteries; AGM and Gel. They get these names because of the mechanisms used to allow oxygen migration.

Absorbed Glass Mat (AGM) Batteries

Deep-cycle AGM batteries incorporate a porous glass mat separator that has the ability to absorb a large amount of electrolyte while still allowing some of the pores to be unfilled. These empty pores act as channels which allow oxygen to move from the positive to the negative plates. This absorptive glass mat is a critical component of the battery since it must be capable of high compression so that good contact can be maintained between the separator and the plates. It must also have high wettability and porosity.

Here are some of the advantages of using deep-cycle AGM batteries:

- **Less expensive than deep-cycle Gel batteries.**
- **Wider temperature range than deep-cycle Gel or FLA batteries.**
- **Slowest self-discharge rate of FLA, AGM and Gel batteries.**
- **Best shock/vibration resistance of FLA, AGM and Gel batteries.**
- **Best for high power applications of FLA, AGM and Gel batteries.**

Here are some of the disadvantage of using deep-cycle AGM batteries:

- **Don't perform as well as deep-cycle FLA or Gel batteries for systems that require regular deep discharge. (i.e. 80% DOD)**
- **Do not perform as well as deep-cycle Gel batteries in low power applications.**

Gel Batteries

Deep-cycle Gel batteries also work on the same principle of oxygen recombination but use a different method to achieve it. They use a composite separator composed of a glass mat bonded to a porous polyethylene or polyvinylchloride sheet. The batteries are filled with a thixotropic gel of silica mixed with sulfuric acid. When this is added to the battery it fills all of the available space and then sets to form a solid matrix. Because all the pores in the separator are filled there are no oxygen channels and in the early stages of its life the battery behaves in the same way as a flooded type with gas generation and water loss. This causes the gel to dry out, shrink and develop cracks which eventually form the channels for oxygen to migrate to the negative plate and be recombined.

Here are some of the advantages of using deep-cycle Gel batteries:

- **Perform better than deep-cycle AGM batteries for systems that require regular deep discharge. (i.e. 80% DOD)**
- **Perform better than deep-cycle AGM batteries for low power applications.**

Here are some disadvantages of using deep-cycle Gel batteries:

- **More expensive than deep-cycle FLA or AGM batteries.**
- **Do not perform as well as deep-cycle FLA or AGM batteries in cold temperatures. (<40 degrees F)**
- **Do not perform as well as deep-cycle FLA or AGM batteries when they regularly reach a shallow depth of discharge. (i.e. 20% DOD)**
- **Higher self-discharge rate than deep-cycle AGM batteries.**

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Battery Considerations for Renewable Energy Applications

In summary, the most important difference between FLA and VRLA batteries is in the oxygen recombination mechanism which eliminates the need to add water to VRLA batteries. While this makes VRLA batteries maintenance-free, it also prevents the addition of water so they are maintenance-proof as well. The elimination of water addition is a valuable feature where the battery installations are in remote areas or where access to the batteries is difficult. However, a penalty is paid for the maintenance-free feature. Their cost of VRLA batteries is higher than flooded batteries and their life is shorter. The shorter life results primarily from their higher operating temperature. The oxygen recombination process produces heat which cannot be shed from the batteries because of the elimination of gas venting. On the other hand the gases emitted from a flooded battery provide considerable cooling. This high operating temperature can shorten the life of the battery by increasing the rate of positive grid corrosion and drying out.

VRLA batteries are preferred in installations where access is difficult or space is limited. Their ability to be operated in any position allows them to be used in spaces where flooded batteries cannot be used, but it is best to use VRLA batteries in an upright position except for large stationary cells designed to be operated in a horizontal manner. There are also important differences between AGM and Gel VRLA batteries. Gel batteries are generally superior to AGM in recovery from deep discharge because they contain more electrolyte and are less susceptible to stratification than either flooded or AGM batteries. Gel electrolyte has a higher resistivity than fluid electrolyte therefore Gel batteries have lower high rate charge and discharge capability than AGM and flooded types.

The advantages of flooded batteries are their well-proven reliability, their long deep discharge cycle life, and their lower cost. They can be made from thick antimony alloy grids which are more suitable for long cycle life than the calcium alloy grids typically used in VRLA batteries. They contain more electrolyte than VRLA batteries which provides good deep discharge recovery and which also acts as a heat sink to keep them cool. Another advantage is that they can be maintained by addition of water. In installations which use a large number of batteries automatic watering systems can be used that increase reliability and reduce labor cost.

Flooded batteries have been used in deep cycle applications for many years and they have been optimized for this type of service. On the other hand VRLA batteries were developed for standby power applications where there is very little cycling, therefore many are not optimized for repeated deep discharging. It is important, therefore, to make sure that a true deep discharge VRLA battery is chosen not a relabeled UPS or standby telecommunications battery. To protect against this the VRLA battery should only be purchased from a reputable manufacturer that specializes in deep cycle technology and who is willing to provide certified life cycle data. Another consideration when choosing between gel and AGM batteries is the effect of temperature on performance. The capacity of gel batteries is reduced more than either flooded or AGM batteries at low temperature.

In renewable energy installations where maintenance is virtually impossible or where very large numbers of batteries are used resulting in costly maintenance, a VRLA battery is a suitable choice. If the duty cycle involves deep discharge cycling a Gel type may be preferred over an AGM type, however many renewable energy systems are sized to 20% to 50% depth of discharge so an AGM battery would suffice. Where the batteries are accessible for maintenance and maintenance costs are reasonable, flooded batteries will have several advantages over their VRLA counterparts.

Trojan Battery Company: Founded in 1925, Trojan Battery Company is one the world's leading manufacturing deep-cycle batteries and four ISO 2000:2001quality management certified plants within North America, Trojan Battery Company supports its renewable energy clients through a worldwide network of master distributors in over 50 countries. With the largest R & D facility in the USA dedicated to performance testing of deep-cycle batteries, Trojan battery continually monitors product performance under true life cycle conditions. This dedication to continual product improvement allows us to set the standard for quality and longevity in deep-cycle batteries used in off-grid renewable energy systems.

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