RESERVE POWER HYBRID SYSTEMS
APPLICATION OF VRLA BATTERIES

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ABSTRACT

A "hybrid" application is characterised as one where the stationary battery is continuously charged and discharged in a controlled cycle, working in parallel with another power source. A typical example would be a 12 hour cycle, where both the load is supplied and the battery is recharged by a generator, followed by 12 hours without generator power, where the battery supplies the load. In this application, cyclic control is required to ensure that the battery achieves its 12 hour discharge, and is fully recharged by the generator in 12 hours, ready for the next discharge.

Stationary batteries in countries where mains grid power is reliable are there to protect in case a mains failure occurs, therefore have a low cycle life requirement. The applications where the stand-by battery is constantly discharged require an optimized battery design. Considerations for cycling and float will be reviewed.

This paper will describe typical stand-by and cyclic applications, their failure modes and the required product requirement to perform adequately.

In order to optimise the economics of such system, the goal will be to maximise the battery time and minimise the charging time. We will describe typical systems using advanced AGM battery design as well as large gel products.

Note: Some of the wording used in the paper is chosen specifically for ease of understanding the lead acid battery system. They are not necessarily addressed to the lead acid battery specialist but rather the user of such systems.

CONSTRUCTION OF A VRLA BATTERY

The principle of the lead acid cell can be demonstrated with simple sheet lead plates for the two electrodes dipped into a diluted sulphuric acid solution; however it will have a low capacity. The amount of energy stored is proportional to the surface area in contact with electrolyte. The lead plates are actually a grid with holes filled with a paste. The role of the grid is to collect and carry the current generated by the paste. The paste is where the energy is stored, and where the current is created. This paste is a mixture of lead oxide (more simply lead powder) plus diluted sulphuric acid. This paste is very porous and increases the surface area considerably. During charge and discharge process the paste increases and decreases in volume; it is therefore very important to take into consideration this phenomenon. The paste will be referred to the "active material" in the paper.

Between plates, and to avoid electrical short, a separator is used. This highly porous material allows ions and oxygen to go through it, but has to prevent formation of dendrites, and filter the migration of impurities from one electrode to the other.

During discharge, the sulphate held in the sulphuric acid solution is transferred into the paste to form lead sulphate crystals. During the charge, the lead sulphate crystals are transformed back into their original structure and the sulphate pushed back into the electrolyte solution.

TYPICAL VRLA BATTERY FAILURE MODES

VRLA failure modes have been described many time in the literature, I will therefore mention what can be observed by the user and will not enter into deep technical considerations. This section is quite important to understand why the right selection of batteries is important in such applications.

Sulphation:
Active materials when in contact with sulphuric acid will naturally transform into lead sulphate. In storage this is the cause of the self discharge phenomenon. On charge this can result from a low charge voltage. Lead sulphate has a crystalline structure, and the crystals will get bigger with time unless any counter-acting measures are taken. Eventually the active material in this condition would become inert as those crystals become difficult to break.

Grid corrosion:
One of the electrochemical reactions of any lead acid battery during charge is the transformation of the lead metal of the grid into lead dioxide; this is positive grid corrosion. The speed of corrosion is a function of many parameters: temperature, charge voltage, acid specific gravity, lead alloy, casting process used. It cannot be fully stopped, but it can be limited or reduced.

Active material deterioration:
During charge and discharge processes, we said earlier that the active material volume will change. Depending on the initial structure of the active material, it can progressively lose cohesion and its porosity, and as a result lose its surface area in contact with sulphuric acid. The energy stored is then progressively reduced.

Acid stratification:
Acid stratification may not be a failure mode in itself, but accentuates the modes described above. Stratification is a phenomenon in which the acid specific gravity is progressively increased at the bottom of a cell. During each discharge-charge cycle, the sulphate is transferred between the plate and the electrolyte. The density of sulphate being high, if there are no preventive actions, will gravitate to the bottom of a cell. The electrolyte will then have higher specific gravity at the bottom of a cell than at the top. The choice of design solutions and selection of material can minimize this phenomenon.

TRADITIONAL STANDBY APPLICATION

Traditional standby applications in countries where the grid network is reliable uses batteries for backup power, but those batteries are rarely used. Those batteries are constantly on charge to compensate for the self-discharge of any lead acid battery system. To do so, they are slightly overcharged, they are on the so called “float” charge mode. Should an outage occur, they are then capable of providing the whole energy stored. One can say that in USA, Canada, Western Europe… those discharges are not happening every day, maybe only several times in a year. Batteries are, therefore, constantly on overcharge, they are designed to fulfil their design life in that mode. They are submitted mainly to the grid corrosion mode. To do so, battery manufacturer increase lead content into the grid or select specific grid alloys. To be noted, pure lead without any other metal has the lowest speed of corrosion.

However, users can observe premature failures caused by the sulphation mode. This happens if the float voltages are inadequate, and/or there are many discharges with inadequate recharge settings.

TRADITIONAL MOTIVE POWER APPLICATION

Motive power applications in the handling sector (lift truck, pallet trucks…) use batteries in a different manner. Batteries are discharged and recharged every day. They are subjected to different failure modes: sulphation should the recharge be inadequate, active material shedding, corrosion and the additional effect of stratification. Therefore to ensure the integrity of the battery, its design is different from standby batteries.

HYBRID APPLICATION

Applications where mains grid network quality is poor or non-existent rely very often on a diesel generator to provide either backup power, or the whole power to their applications. Main applications are:

- Telecom BTS off-grid site
- Off-grid power for households

In the last 2 years, as we all know, fuel cost had increased dramatically to peak in summer 2008. During this period many users have looked for ways in reducing their fuel cost, but also overall cost of such systems.

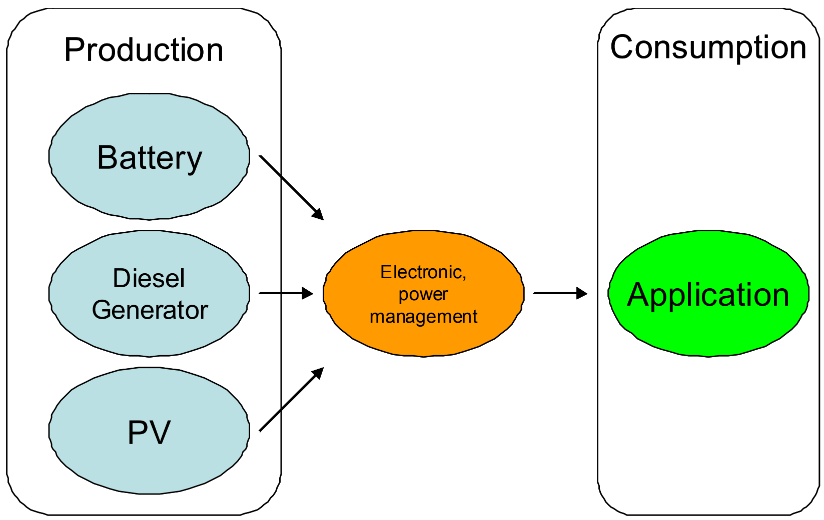
The remote off-grid telecom sites often use 2 diesel generators to ensure constant power to the systems; in addition, some have a battery for backup.

Operators have realized that they could generate saving if the batteries were actually used for longer duties, the savings could be generated by:

- reducing generator time and therefore fuel consumption
- extend generator maintenance intervals
- use only 1 generator instead of 2

The concept is therefore to use the battery as a primary source of energy in a cyclic operation instead of a backup. The system would typically discharge the battery everyday during the night, and recharge thanks to the diesel generator during the day. This battery is closer in its application to the motive power battery than a standby battery. The potential failure modes are then the ones of the motive power.

Many configurations exist combining several power sources: photovoltaic, wind, hydro or generator in addition to the battery. We will assume in the examples below that the battery has a major role as an energy source:



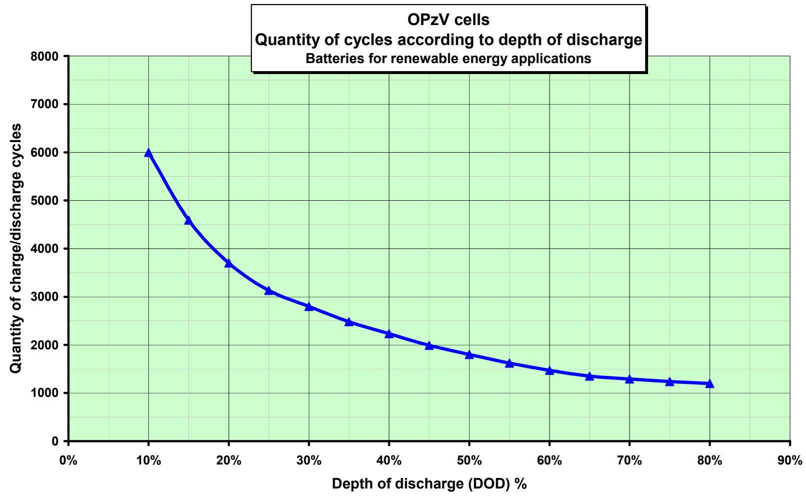
Typical systems using a diesel generator and a battery

Users would like to save the maximum of fuel, and run on batteries as much as possible. However several aspects of the battery are quite important to achieve the expected lifetime. Here is a list of criteria needed to size such system:

- Cycle life, effect of depth of discharge
- Time to recharge and end of charge detection
- Available charging current
- End of discharge cut-off

Cycle life, effect of depth of discharge

This is a key parameter to correctly size a system. VRLA battery cycle life is dependant on the amount of energy discharged at each cycle. As a general rule, we can say a given battery is capable of providing a certain amount of Ah in its whole life. If a small amount is discharged at every cycle, the battery would be able to provide many cycles. On the opposite, depleting the whole capacity at each cycle would result in shorter cycle life. Of course this is general rule and each manufacturer and battery design would slightly differ. Graph 1 is an example of a typical Enersys OPzV curve.



Graph 1

Typical systems would be sized for 3 to 5 years in operation, therefore in this example between 1100 cycles and 1800 cycles (1 cycle per day). From this chart this would result in depleting between 50% and 70% of the battery capacity at each cycle. Maximising the cycle life is possible at the expense of over sizing the battery; payback calculation would determine the optimum battery size. Also to be noted, that it is typical in the battery industry to define end of life when the battery reaches 80% of its capacity. Users that need full discharge time at the end of life would have to factor this in.

Time to recharge

The charge algorithm used is essential to the success of such system. The systems often use many battery elements or blocs in series, and to achieve the expected cycle life they have to be fully recharged and homogenous at each cycle. In those applications, the use of float charging voltages commonly used in stationary applications is not suitable. Actually, to fully recharge a typical 2V cell on float charge, 24h is required, if it has been discharge to 80% of its rated capacity. For OPzV, elevated voltages are recommended (typically 2,35Vpc or above) for a daily discharge at 50%. The recharge time in those conditions could be lower than 12h. Recharge time can be reduced even lower (2 to 3 time) with alternative batteries using thin plate pure lead technology, should the available current be sufficient.

Charging current

Enersys' extensive experience in motive power applications (lift truck…) tells us that there is a minimum current to properly charge at each cycle a battery. Charging time is a function of the available current. Also for optimizing such a system, the user would like to use the generator for the minimum time to recharge the battery; therefore, the use of a larger than initially thought generator might be required.

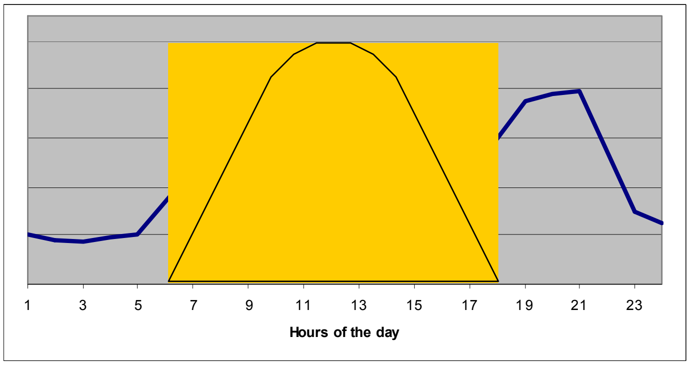
This parameter is important; however, in many instances, a generator already exists on the different sites and could possibly be a sizing factor. During the generator time operation, it has to provide power to the application and to the battery for its recharge. For example an OPzV would have an optimized cycle life, should the charging current be more than 0,17C10, or 170A for a 1000Ah battery.

End of discharge detection

As discussed above, deep discharge will affect the cycle life. It is therefore important to detect the end of discharge, when the calculated depth of discharge is achieved. This can be achieved by counting Ah in recent power systems. However in many systems this option is not available. In those conditions, the battery manufacturer can estimated the cut-off voltage to a given depth of discharge. However this value is highly dependant on discharge current and a site specific setup might be necessary to achieve the best results.

Typical systems using a diesel generator and a battery and PV

Some systems also use photovoltaics to further reduce the fuel consumption. As we can see in the graph 2 below, the curve is showing the average household energy consumption, with in yellow the energy that could be created using photovoltaic panels. Batteries would store the energy generated by the PV. The generator would be used only during peak load and to recharge the battery should the PV output not suffice.



Graph 2

Example of application using OPzV batteries (tubular positive plates)
System to power telecom cellphone BTS system:

- 48v system, load of 1600W, 17kVA diesel generator
- 1 string of OPzV800 discharged at 50% can provide 13,5h discharge time, and 13h recharge
- Expected life of 4,8 years for a system that run 50% of the time powered by the battery and 50% with generator.

Example of application using thin plate pure lead batteries, reducing diesel generator time
Using same system as above

- 48v system, load of 1600W, 17kVA diesel generator
- 5 strings of SBS190 discharged at 60% can provide 17h discharge time, and be recharged in 6h
- Expected life of 3 years for a system that runs 75% on the battery and only 25% of the time with the generator.

Both systems have demonstrated that they would save significant fuel, and that payback would justify such an investment. Field data from systems installed since 2006 have demonstrated the validity of such solutions.

CONCLUSION

Hybrid systems using several energy sources can use VRLA batteries as one of the main sources. In those conditions the battery is discharged daily and is exposed to significantly different conditions than traditional standby application battery. The battery in hybrid application needs therefore to be selected in accordingly. The charging conditions are a key factor in achieving the expected life. It is often observed that a case by case study is necessary to achieve the most optimized systems.