THE IMPORTANCE OF TESTING PV BATTERIES TO THE IEC 61427 STANDARD

BACKGROUND

Batteries in photovoltaic systems (PV) are unique in how they are used because recharging them is primarily dependent on the vagaries of the weather, and proper charging is crucial to getting the most life from a deep-cycle battery. In addition, experience has shown that batteries in PV systems are routinely undersized either due to cost considerations or because the loads were underestimated for the system.

As a result, life expectancy of PV batteries is difficult to quantify – until now. The International Electrotechnical Commission's (IEC) standard 61427 titled *Secondary cells and batteries for photovoltaic energy systems (PVES) – General requirements and methods of test* provides performance criteria that all batteries for PV applications can and should be measured against. It offers a common, internationally-accepted platform to compare and contrast batteries from different manufacturers.

DEFINING BATTERY LIFE EXPECTANCY IN A PV SYSTEM

Traditionally battery life has always been defined either as *float life* (how many years it takes the battery to reach end of life at a specified reference temperature) or as *cycle life* (the number of times a battery can be continuously charged and discharged before it reaches end of life.) It is worth examining in more detail what is meant by float life and cycle life of a battery.

In a float application, the battery is simply a source of backup power, such as in an uninterruptible power supply (UPS) system. In a UPS system, the traditional AC grid provides the power, but in the unlikely event of a grid failure the battery kicks in to power essential loads until power is restored from the grid. Until a grid failure occurs, the battery is kept on a continuous float (or trickle) charge, which can last for years at a time depending on the overall reliability of the AC grid.

Therefore, in a float application, the battery is not charged and discharged on a regular basis. In other words, a battery is not cycled in a float application. A battery is said to be cycled when it is repetitively charged and discharged in succession.

In each case, to express a battery's life expectancy, the underlying assumption is that any particular application can be unambiguously seen as being either a float or cycling application. However, the reality is that renewable energy (RE) applications such as PV power systems are deep-cycling applications, although there is an emerging trend for backup power that requires the batteries to be in a hybrid mode. This places batteries somewhere between true float and true cycling applications.

Since neither float life nor cycle life adequately describes the expected life of a battery in a RE application, an alternate method is needed to specify battery life in a PV system, and the IEC 61427 standard offers a possible way to do that. This standard test protocol uses elevated temperature (40°C or 104°F) and a series of shallow cycles to simulate a real-world PV application. The battery being tested is considered to have reached end of life when its capacity drops to less than 80% of its rated capacity[1].

CAN PUBLISHED CYCLE LIFE CHARTS BE USED TO ESTIMATE PV BATTERY LIFE?

Deep-cycle battery manufacturers publish cycle life charts that show the relationship between depth of discharge (DOD) and the number of cycles delivered by the battery. To generate these charts the batteries are charged and discharged (cycled) continuously in a laboratory under controlled conditions. These controlled charge and discharge conditions ensure that the batteries are never undercharged or overcharged; nor are the batteries cycled at partial states of charge (PSOC), a situation that is very common in a PV application. Since predictable charge or discharge rarely occur in a PV system, estimating the life of a PV battery using a typical cycle life chart is discouraged as it will not be representative of a field situation.

While the cycle life chart found in a manufacturer's literature does an adequate job of predicting the cycle life of a battery in a normal cycling application[2], it is not nearly as effective in estimating battery life in a PV application because of the various uncertainties associated with a PV system. The logical question that now arises is this: If neither float life nor cycle life applies to a PV battery, how should one go about estimating its life?

In this paper we will use the **term service** life to refer to the life of a battery in a PV application. **We will define the service life of a PV battery to be the number of cycles the battery delivers when tested to the IEC 61427 standard.** Since one IEC 61427 cycle consists of 50 shallow cycles at low state of charge (SOC), and 100 shallow cycles at high SOC equals one year of actual service in the field, the service life in years of a PV battery is equal to the number of IEC 61427 cycles it delivers before its capacity drops to 80% of its rated capacity. The two equations below illustrate the simple relationship between the number of IEC 61427 cycles delivered by the battery and its service life in years.

1 IEC 61427 cycle=(50 shallow cycles at low SOC)+(100 shallow cycles at high SOC)
1 IEC 61427 cycle=1 year of service life in a PV application

1 - For example, a 100 amp-hour (Ah) battery will be considered to be at end of life when it does not deliver at least 80Ah in a capacity test.

2 - A "normal cycling application" is one in which the battery is repetitively discharged to a fixed DOD and fully charged prior to the next discharge.

Based on the second equation shown above, if a battery delivers 15 cycles to the IEC 61427 standard's requirements, the battery has a service life of 15 years in a PV application.

THE IEC 61427 STANDARD

The IEC, recognizing that batteries in PV applications take on the characteristics of both float and cycling applications and are heavily cycled at PSOC at temperatures higher than 25°C (77°F), has developed a standard protocol that simulates a real-life PV application. The test subjects the battery to a series of shallow DOD cycles under low and high SOC.

The basic assumption is that the PV battery is charged during the day and discharged during the night, with the typical discharge each day consuming between 2% and 20% of the battery's amp-hour capacity.

As shown in the Phase A and Phase B tables below, the IEC standard accounts for the effects of seasonal cycling variability – winter cycling with low solar irradiation is simulated by cycling at low SOC (Phase A), and summer cycling with high solar irradiation is simulated by cycling at high SOC (Phase B). This seasonal aspect of the cycling test incorporated in the IEC 61427 standard is another reason why testing a PV battery to this standard provides superior life expectancy estimates, than those offered in standard life cycle charts published by battery manufacturers.

In addition, the standard subjects the battery to PSOC cycles in which the batteries are discharged before they are fully charged – a very common occurrence in RE systems. This requirement significantly reinforces the applicability of the IEC 61427 standard to batteries for PV systems.

Combining the effects of seasonal (winter/summer) cycling and PSOC cycling to estimate the life of a battery in a PV application is far more representative of the service a PV battery will be subjected to in an actual application. Therefore, when estimating a battery's life in a PV application, Trojan strongly recommends that the IEC 61427 standard be used as the primary benchmark. It is a much more reliable estimate of the battery's life in a PV application than a manufacturer's standard cycle life versus DOD chart.

TEST REQUIREMENTS PER IEC 61427

The IEC standard calls for 50 shallow cycles at a low SOC and 100 cycles at a high SOC. The temperature of the test is maintained at 40°C (104°F). At the end of these 150 total cycles, the battery is load tested to check its capacity – if it is at least 80% of its rated capacity the battery is subjected to another sequence of 150 cycles. If not, the battery is considered to have reached its end of life. The test protocol is summarized in the two tables to the right.

CONCLUDING COMMENTS

Estimating battery life expectancy in a PV application poses special challenges due to a variety of unknown factors, primarily related to intermittent weather conditions that impact both the charging and discharging phases. Further complicating the issue, is the tendency to underestimate the battery capacity required to power the loads.

Since a typical PV application is mainly cyclic in nature and cannot be correctly classified as either a float application or a true cycling application, an alternate method is required to specify battery life in a PV application. The IEC 61427 standard provides that method. Because the conditions of the test simulate the following key characteristics of a typical PV application, the IEC 61427 standard is particularly well suited to offer better insight into the life expectancy of a battery in a PV application.

- Test temperature (40°C or 104°F) is warmer than normal room temperature and more representative of an actual PV battery system installation.
- Seasonal (winter/summer) cycling accounts for variable charging during the year, which is true for PV applications.
- Partial state of charge (PSOC) cycling allows for batteries to be discharged before they are fully charged – a very common occurrence in PV applications.

When a PV system designer is evaluating battery options for use in PV installations, the IEC 61427 standard should be used as the benchmark to compare and contrast the batteries being considered for the application. This ensures an apples-to-apples comparison which guarantees that each deep-cycle battery option is tested in exactly the same way.

More importantly, since the IEC standard subjects the battery to a set of operating conditions that more closely resemble what it will actually face in the real world, the results of the IEC test will provide the closest estimate of the battery's service life in an actual PV application.

Phase A: Shallow cycling at low SOC per IEC 61427			
Step	Discharge time, hrs.	Charge time, hrs.	Current, A
(a)	9		I_{10}
(b)		3	$1.03I_{10}$
(c)	3		I_{10}
Repeat steps (b) and (c) 49 times, then proceed to Phase B			

Phase B: Shallow cycling at high SOC per IEC 61427			
Step	Discharge time, hrs.	Charge time, hrs.	Current, A
(a)	2		$1.25I_{10}$
(b)		6	I_{10} (Voltage limited to manufacturer's recommendation)
Repeat steps (a) and (b) 99 times			