Performance and Service Life Advantages ALM® 12V7s for Electric Grid Substations

SUMMARY

A substation is part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, and several other important functions. Between the generating station and consumer, electric power may flow through several substations at different voltage levels. Depending on the region, they are owned and operated by electric utilities Transmission or Distribution System Operators (TSO/DSO), or a large industrial or commercial provider.

Substations are categorized in two main groups.

Primary or Transmission substations: Energy is transformed from transmission lines (typically >100 kV depending on the region) to sub-transmission or distribution circuits (2.4 kV to 33 kV). High voltage is used to 'transport' energy between large energy production plants (thermal, nuclear, hydro, etc.) and secondary substations located close to end users.

Secondary or Distribution substations: Transforms sub-transmission medium voltages to lower levels for "last mile/kilometer distribution. Many European systems have small neighborhood secondary substations converting to the final service voltage, while most North American systems use separate distributed transformers.

KEY TRENDS

Electrical substations can be numerous and deployed over a wide geographical region. The management of these sites, particularly in remote areas, is challenging and costly. Generally, each substation has a remote system that operates on site communications and control during a grid outage and to reestablish normal conditions once the grid is restored. For this reason, each substation has an Uninterruptible Power Supply (UPS). The UPS provides backup power to the site equipment and for grid switch maneuvers. Typically, lead acid batteries are used in the UPS and need regular maintenance and replacement to guarantee the reliability of the system. In the case of critical sites where temperature extremes and frequent blackouts occur, the battery service life can be 2 years or less.

Since the substation maintenance and reliability is essential, lead acid batteries can be the weak link for critical sites. System operators need long service life batteries in tough, critical conditions such as high temperature and deep depth of discharge (DOD).

BACKUP POWER ATTRIBUTES & CHALLENGES

The UPS provides power when the grid becomes unavailable to maintain communication equipment and to command remotely the necessary maneuvers of grid switches. These switches open and close electric circuits to maintain power to the grid. The typical load from the communications devices is 50 - 100W. In addition, the grid switches present a typical load of 300 - 500W and are opened and closed over repeated intervals to ensure reliable contact. Site back up power autonomy is generally 2 hours or greater. To achieve this, lead acid battery sizing is 2X – 8X nameplate capacity to deliver the correct site power and to keep the DOD to a manageable level. Lead-acid batteries experience capacity and life derating according to the DOD level and discharge rate.

Substations usually do not have climate control and in some regions can experience wide temperature fluctuation. For this note a site range of 0 - 50°C, with an average of 25°C is considered. During warm seasons, averages can be 35°C. The combination of high temperatures and 50% DOD impacts the service life of lead acid batteries, leading to frequent maintenance and replacement.

NEC Energy Solutions ALM® lithium ion batteries are robust, safe, and light weight with over 20 years of service life. They are well suited for substation UPS applications due to their high power capabilities even to 100% DOD. This allows the full capacity of the battery to be used, without the need for nameplate capacity oversizing. This combination provides the site with a reliable and durable UPS with little maintenance and low total cost of ownership. Figure 1 shows the ALM® 12V7s capacity fade.

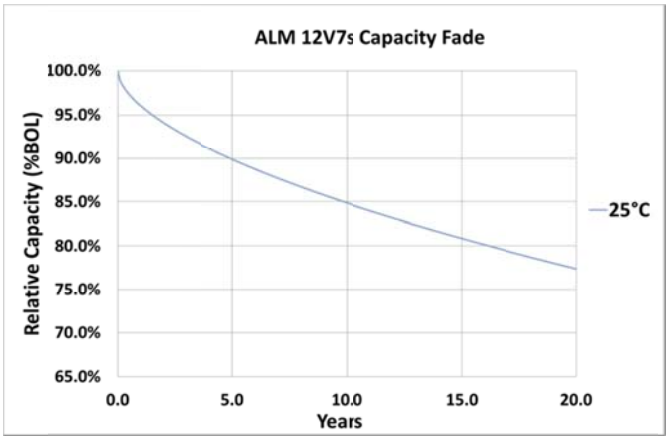

Figure 1

COMPARING BATTERY ARRAY POWER SYSTEMS

Using requirements for a secondary substation UPS system, NEC Energy Solutions compares its ALM® 12V7s battery against a well-known lead-acid battery. The operating period is 20 years.

Target requirements are:

- Peak power: 300 W
- Average load: 50 W @ 24 V nominal
- Run time: 2.4 hours.
- Average Temperature: 25°C

In most outages, less than 123 Wh are needed, with outages lasting less than 2.4 hours before the grid recovers or the problem is fixed.

Metric	ALM	SLA	Unit
Target System Size (Energy)	123		Wh
Ave Power Delivery	50		W
Target Temperature Range	0-50		°C
Ave Load Discharge Duration	2.4		Hours
Peak Power	300		W
Nameplate Capacity (per Battery)	5	25	Ah
Nameplate Energy (per Battery)	66	300	Ah
Safe DOD level	100%	50%	%
Average Usable Energy per battery	66	150	Wh
# Batteries	2	2	#
Total Usable Energy	132	300	Wh
Expected Service Life	20.0	3.0	years
Number of Replacements	0	6	#
Total Weight (kg)	1.8	18	Kg

Figure 2

SOLUTION

The ALM 12V7s uses lithium iron phosphate ($LiFePO_4$) cells that provide excellent deep cycling capabilities, extended temperature, long service life and exceptional power and energy performance. The ALM 12V7s family includes EverSafe™ protection technology as part of the Battery Management System (BMS) in each battery. This technology delivers fully redundant protection from internal failures or external abuse like accidental short circuits, and recovers from them automatically. It provides system-level protections for battery strings and power system operation, with automatic adjustments and recovery from system level faults or abusive application.

The 24V supply requires two ALM 12V7s batteries connected in series. These deliver 132 Wh at 25°C.

1.) Excellent power and runtime performance

The ALM12V7s allows 100% DOD at high power up to more than 300 W for each module. This means that the ALM 12V7s can deliver 100% of the capacity in real operating conditions. The voltage characteristics allow critical switch maneuvers when the battery is close to 0% State of Charge (SOC). Under these conditions, lead-acid batteries' service life is shortened.

2.) Service life, total cost of ownership

Under a reliable grid environment, high quality lead-acid batteries achieve a calendar life of 7 - 10 years at 25°C. The life is reduced in half by every 10°C increase, with a calendar life of 3 - 5 years at 35°C. The ALM 12V7s service life is greater than 20 years at 25°C to 75% beginning of life (BOL) capacity (figure 1). Over this period, the lead acid batteries need to be replaced 6 times in order to provide the power back up needed from the UPS system.

To replace the batteries, the service costs (transportation, labor) could be up to 5x the cost of the battery. For remote sites the cost can be higher. Figure 3 shows the life cycle cost comparison over a 10 year period. The total cost of ownership is significantly lower with the ALM 12V7s since it requires no replacement. For 20 years it is even lower.

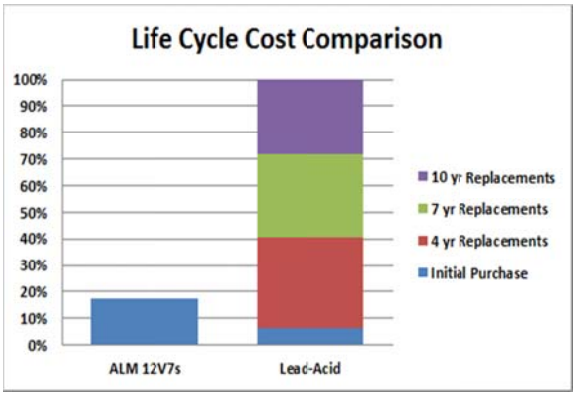

Figure 3

3.) Significantly less weight and volume than lead-acid batteries

The low weight of the ALM 12V7s eases installation, with each battery only 0.9 kg. For remote and hard to reach installations this is very important. The lead-acid batteries are about 9 kg, 9 times heavier than the ALM based system.

4.) Low self-discharge

The DSOs require a large inventory of lead-acid batteries in their storehouse ready to be used in the event of a service call. Lead-acid batteries have to be periodically charged, typically every 6 months, due to self-discharge. Failure to maintain the proper SOC could cause irreversible damage and void the battery warranty. For the ALM 12V7s, stored at 100% SOC, the shelf life is 2 years. Periodic recharge is not required during the time period, which reduces the maintenance cost significantly compared to lead-acid batteries.

NEC Energy Solutions ALM family of lithium-ion batteries are highly engineered, with quality construction, evaluation, and extensive testing to ensure international product safety conformity, as well as application specific certifications.

Details on design, safety, and compliance can be found in the NEC Energy Solutions white paper: **Lithium-Ion Battery Design for Safety.** Visit **www.neces.com** for the latest information and data sheets.