BATTERY SELECTION, INSTALLATION, AND MAINTENANCE FOR CELLULAR TELEPHONY

Allen Byrne and George Pedersen
PowerConsult
Frederick, MD 21704

Overview.

Batteries are critical components in cellular telephone systems. In the remote, unmanned, and sometimes hostile environment that the majority of the carrier equipment is deployed, batteries are depended upon to provide reserve power on demand. All too often, the selection, installation and maintenance of these components are handled by telecommunications professionals who are not knowledgeable about batteries or charging equipment. On the other hand, the battery suppliers, installers, and maintainers may be unfamiliar with the cellular telephone environment. It is the intention of this paper to be of assistance to all of those involved in the selection, installation, and maintenance process. In keeping with the cellular industry's battery of choice, only the Valve-Regulated Lead-Acid (VRLA) battery will be discussed.

1. SELECTION.

All too often, selection is manufacturer driven mainly because the user relies upon the knowledge and advice of the supplier. Consequently the user may not get what is really required. There are some important details that should be taken into consideration.

- **Physical Size.** The selected battery should consist of cells and modules that can easily be changed out, since it is likely that individual cells, modules, or the complete battery may have to be replaced during the life of the cell site. Allowance should also be made for the possible installation of additional battery strings.

- **Electrical Size.** There are several considerations here, and all reflect upon the cost of the power system. Overestimation of the load not only increases the battery cost but also starts the domino effect. The chargers are oversized, space requirements grow, HVAC sizing escalates, installation and maintenance costs increase.

  What will the load be? Equipment manufacturers typically overstate the power requirements of their equipment. Get the actual (not worst case) load requirements and get it in writing. Also, talk to users of similar equipment and get some "real" load figures.
  What is the voltage operating window of the load? This will dictate the battery cut-off voltage. Once again, don't purely rely on the load equipment manufacturer, but talk to other users and determine field proven parameters.

- **Reserve Time.** Another difficult choice is how long to "back up" the system? This depends upon many factors such as:

  Is a minimum reserve time mandated by a legislating authority such as a Public Safety Commission?
  Is there an engine generator on site?
  How important is the site in terms of traffic and revenue?
  Is the site environmentally controlled?
  What space is available?
  How accessible is the site?

All too often, a user will simply request a battery that will provide, for example, eight hours reserve, without any consideration as to what will happen during a battery discharge. If the air conditioning and air handling systems are not backed by generator, then the load equipment will probably shut down because of high temperature long before the full capacity of the battery is ever utilized.

- **Configuration.** Once the reserve time has been determined then the battery configuration can be addressed. Here the important decision is whether to have a redundant battery or not. In many cases, going with two parallel battery strings allows for smaller, more manageable battery sizes. Also, parallel redundant batteries greatly assist in battery validation and testing. Bear in mind that almost all cellular systems require a positive 24 volt battery. If there is a sizable 48 volt requirement, then it may make sense to install a separate 48 volt plant rather than use DC to DC converters.

- **Projected Battery Life.** What is the estimated design life of the cellular system being installed? If it is five years or less then there is not much point in putting in a battery designed for in excess of 10 years. Besides, if a lower life battery is selected then, not only will it cost less and probably take up less space, but it will be cheaper to replace should it become defective.

- **Racking and Framing.** The means of housing and containing the battery is often determined by the type of battery selected; however, a choice is usually available with respect to mounting the battery in an equipment rack, as the base for the equipment rack, or in a stand alone configuration. Remember, heat can be a problem in cellular applications; therefore, the choice of battery containment with respect to ventilation and heat management can be critical. Always strive for a system that gives maximum natural convection cooling.

- **Low Voltage Disconnects.** A low voltage disconnect (LVD) is a means of disconnecting the battery from the power system or load at a preset discharge voltage, and the use of a LVD is purely the system designer's choice.

  LVD's can be placed at two points in a power system, either in the load side or in the battery side of the rectifier/chargers. Telecommunications systems typically have an LVD installed in the battery side, as it is considered more fault tolerant because, a failure in this circuit does not immediately jeopardize the load. The LVD can also be used as a battery disconnect in this configuration; however, many manufacturers of telecommunications and radio equipment are insisting that the LVD be placed in the load side. The reason for this is that in this configuration all of the load devices can be prohibited from reconnection to the power system after a battery discharge until the power system bus voltage has returned to a predetermined, acceptable level.

  Redundant and load specific LVD's are also an option. Since a LVD is a single point of failure item, redundant contactors, control circuits, and override circuits should be considered. Multiple LVD's can also be configured to allow for selective load shedding.

  Some telecommunications companies prefer not to use LVD's but would rather sacrifice the battery, and possibly some other equipment in the event of a commercial power failure in order to keep traffic flowing as long as possible.

  In view of all of the above, LVD selection should be a decision arrived at in conjunction with the cellular provider and the telecommunications equipment vendor.

- **Battery Disconnects.** A battery disconnect is a means of removing the battery from the power system. In the authors' opinion, a device incorporating over-current protection is mandated by the National Electrical Code (NEC) Article 240-21. (see Bibliography). Although, considered by some as a single point failure item, from a maintenance perspective, a disconnect means is of particular importance, allowing for a safe and convenient method of removing a battery string from the power system. The coordination of the size of the battery disconnect overcurrent device with the power system capacity, battery size, and interconnection cabling is of prime importance.

- **Charging Voltage and Current.** Almost all cellular power installations are constant voltage systems. In other words, the battery charge voltage is set at a constant level allowing the battery to draw whatever current that may be required at a particular state of charge. The problem that the system designer must be aware of is that because of the oversized and redundant rectifier/charger configurations and load-side LVD systems almost always used, much more current is available during the initial recharge period of a heavily discharged battery than many battery manufacturers feel comfortable with. The battery manufactures have to work with the power equipment manufacturers on this issue; however, nothing much can be done about this problem at the moment, other than the system designer engineering the system capacity properly, and being aware of the situation. Two things that the authors suggest is the disabling of the equalize setting on the power board and the temporary removal of any rectifiers in excess of the "plus one" redundancy.

Charging Voltage and Current continued.

The float voltage should be carefully set and monitored for the particular battery being used as individual manufacturers do have slightly different recommended voltages. In many cases the arbitrary float voltage set by the rectifier/charger manufacturer is never readjusted and may be unsuitable for the battery in use.

2. INSTALLATION.

- **Orientation.** The location and orientation of a battery plant when installed in a separate battery room or conventional facility is normally dependent upon the shape of the room and the achieving of the shortest cable distance between the battery and the rectifier/chargers. In the cellular industry, the prefabricated buildings and other typical locations are much smaller, so the distance from battery to power plant is less important. The space allocated for the battery however, is now often determined by the space left after positioning all of the other equipment rather than the optimum battery location.

  There are two major considerations in positioning a battery plant. First, the location and the orientation of the battery should always be such that an individual cell or module can easily be removed and replaced. Unfortunately, this is frequently not the case, as the authors have seen many installations where other equipment is so close to the face of the battery plant that there is insufficient room to remove a cell fully from the module. (This is also a contravention of the NEC, but that is another story.) The second problem, which may not be so obvious, is the location of the battery with respect to the HVAC units. In a prefabricated building, HVAC units are typically located in the end wall where they force the heated or cooled air down the length of the building. One unit typically blows over the radio equipment with the second unit being directed at the clear space in front of the radio equipment. If, as often happens, two battery strings are installed side-by-side at the opposite wall to the HVAC units, then one string may be in the direct flow of cooled or heated air, while the other may be shielded by the radio bays and other equipment. In situations like this, the authors have measured a differential of up to eight degrees Fahrenheit, between the ambient surrounding the individual battery strings. This can and will result in the two battery strings having differing charge requirements and operating lives.

  Some manufacturers employ adjustable pressure plates at the side of the battery module frame. Because tool access is required to the adjusting mechanism, care should be taken to accommodate this.

- **Connections and Cabling.** Because of the close proximity of all of the equipment in a typical cellular radio site, it is very important from the point of personnel safety, that the battery terminations are protected from accidental contact. This can be achieved by ensuring that all covers are adequate, properly installed, and cannot be easily dislodged (battery manufacturers please take note), and also by considering how the battery cells should be strapped to optimize the choice of take-off locations. Battery disconnects with overcurrent protection should be installed to comply with the NEC; however, the selection of these devices and the associated cabling should be carefully analyzed. Where it might seem obvious that the rating of an overcurrent device must be smaller that the cable it is feeding, it is common to find sites where 600 ampere fuses and even 1200 ampere circuit breakers are being used in disconnects wired with a single 4/0 AWG cable from a 1300 ampere-hour battery plant. The use of a fuse block as a battery disconnect gives the greatest flexibility in this regard as a range of fuse sizes can be fitted; however, it is essential that the value of the fuse installed (not the capacity of the fuse holder), and the date it was last changed should be clearly marked on the outside of the unit.

- **Grounding.** The grounding and bonding of cellular sites is of paramount importance because of the susceptibility to lightning and other surges and transients. As far as the battery plant is concerned, the battery rack has to bonded directly to the site grounding system using a minimum of 6 AWG wire and the DC return bus (battery negative on a 24 volt system) has to be similarly grounded. For further information refer to ANSI T1.311-1991 (see Bibliography). Any other metallic objects such as battery disconnects and cable raceways should also be directly bonded to the grounding system.

- **Installation Practices.** It has become common practice to use flexible cable when installing cellular power systems. The cable should of course be properly rated for cable tray use but this is not always the case. Welding type cable is much easier to obtain, and for those that have not yet experienced a melt down, it appears to be perfectly suitable. Irrespective of whether the correct cable has been selected, the use of flexible cables allow poor installation practices to proliferate. Just because one can bend the smaller sizes of flexible cables very tightly does not mean that this should be the case as the correct bending radius for the particular size of cable should be maintained.

Installation Practices, continued.

Installers also need to be aware that in the larger sizes, flexible cable has a much larger diameter than the equivalent ampere capacity of hard drawn copper cable, and it is often difficult to achieve the same bend radius as can be achieved with hard drawn copper. Another major problem that can occur in using flexible cable is that it is very easy for the cables to be pulled tightly around objects such as cable ladder supports, which can result in damage to the cable insulation, in particular the soft rubber insulation of welding cable. Flexible cables must also have more frequent attachments to the support structures to ensure the cables don't sag and become obstructions.

- **Standards, Codes, Methods, and Practices.** Many telecommunications companies have long considered themselves exempt from the NEC under Article 90-2-(b)-(4). This, coupled with the fact that many of the standards that were adopted came from Bellcore, and also the unique cellular environment; has meant that many standards and practices were either carried-over or specially adapted and adopted. Some cellular operators have their own specific standards, while others have none at all. (The authors are currently compiling a generic power and grounding installation manual for use within the industry.)

  These standards (or lack of) can apply across the board, covering installation methods, equipment standards, maintenance procedures, and even safety. Care must be taken by the installer to ensure that all applicable standards are followed and that they do not conflict with other standards that may apply. Equally, there must be an awareness of which standards should apply. Obviously, it is not the intent of this paper to be a standards, codes, methods, and procedures tutorial, but some documents that may be applicable are listed in the bibliography.

3. MAINTENANCE

There is probably no other word that can mean so many things to so many people as the word "maintenance" when used in association with batteries. In the authors' own office there is continual discussion as how to best remove the word from the marketing and technical vocabulary, so one can guess what it took to allow it to appear in this paper. The problem is the perception that battery maintenance requires a physical act such as the adding distilled water. "If you can't do that, then you can't maintain it." If this statement seems crazy, then you are neither a marketing person or someone with bean counting responsibilities. In the educated and informed world, however, the word maintenance is variously defined as "to keep in a particular condition", or "to preserve," neither of which definitions say anything about adding water. Now that it is established that water is not the critical element, what constitutes a meaningful maintenance program?

- **Failure Identification.** One thing that all agree upon is that because of the chemical changes that start the moment the battery is manufactured, every cell will eventually fail, and the time from manufacture to failure is very dependent upon the manner and conditions under which the battery is operated. As discussed above, ensuring that the battery has the correct characteristics for the specific application is also a factor in obtaining maximum life. Most would agree that the ultimate test of any battery plant is a closely monitored discharge at the maximum system load, and an equally observed recharge. If that testing is carried out at regular intervals, then the data collected can be used to trend the discharge characteristics of the battery and to predict the end of useful life. What we don't all necessary agree upon is whether it is possible to identify any characteristic changes and trends based only upon the measurement and analysis of cell voltage, charge current, and temperature; or whether the use of stand-alone or integrated test equipment to measure the internal resistance, impedance, or conductance of the individual cells is sufficient to obtain the data on which trending can be based.

- **On-site Testing.** For the cellular industry, the use of portable test equipment would appear to be an acceptable method of routine testing as most sites are visited by a technician at lease every few months; however, experience has shown that such a program requires considerable initial organization and continuous follow-up, in order to be successful. The sites have to first be audited, surveyed, tested, and a database established with baseline information for each battery string. This can be carried out by the cellular technicians who are going to be responsible for the ongoing system testing and support. But if the network is an established one, with the sites and battery plants having been brought on-line over several years, it is often better (although more costly) to use a qualified power engineer with considerable battery experience to determine the battery condition based upon not only the static readings but also the physical and environmental conditions.

On-site Testing continued.

The adequate training of the cellular technicians responsible for ongoing system testing is a must, and because of the high turnover within the industry, this training may be required at quite frequent intervals. A schedule for data collection has to be established and the collected data must be entered into a suitable database to allow for continuos analysis. There is also a fear factor that has to be overcome, the fear of the "high voltage" power plant and the associated battery that seems to exist with telecommunications technicians more familiar with a few volts and milliamperes.

The authors are currently working with two clients on such a technician training program and it may be interesting to report on the success or failure at a future conference.

- **Remote Testing.** In the cellular industry, the sheer number of sites and batteries involved, tend to preclude the use of expensive, integrated test equipment that could be accessed remotely, and this is purely because of the capital cost. Most available capital is currently being used to expand the installed base to maintain a competitive advantage over the new license holders and PCS carriers.

  There is, however, an alternative test means that has been integrated within some of the power plants that have been installed over the past few years. This feature allows the output voltage of the rectifier/chargers to be remotely reduced below the open circuit voltage of the battery, at which point the battery is forced to support the load. The rectifier/charger voltage however is kept above the minimum operating voltage of the load equipment and the low voltage disconnect set-point (if installed), so in the event of a catastrophic battery failure, the load is still protected. If this test is carried out on a routine basis and the discharge curve is remotely logged to allow trending analysis, then a reasonable confidence level can be assumed in the battery's performance, down to the reduced voltage level.

  Existing local test equipment and remote monitoring devices tend to be too complicated from a user perspective, and too expensive with respect to battery plant initial cost.

- **Warranty.** There is a move in the industry by some manufacturers to differentiate themselves by extending the warranty to a full 5 years unconditional under normal operating conditions. This has to be good for the industry as it indicates a greater confidence by the manufacturer, that under the proper conditions, the battery will perform as specified. It also places a responsibility on the user to ensure that the battery plants are operated under the best conditions possible and that adequate records of operating conditions are maintained in order to support any possible warranty claims. Indeed, manufacturers may start monitoring their own batteries. It would also benefit the manufacturers to do a better job in educating their customers with respect to maintenance.

CONCLUSION.

The battery manufacturers in the past have got a lot of bad press concerning battery performance and life, and some of the complaints were justifiable. Most of the cellular industry is still young, but they are beginning to see battery failures and the authors sense another wave of resentment against the manufacturers looming. Close cooperation between manufacturer, integrator, and customer, in the battery selection process, based upon a knowledgeable approach, is required. Proper installation and meaningful maintenance is a must if the battery system is to provide adequate service, and a continuing dialog between manufacturer and user is necessary to promote understanding and confidence.

Note. The authors will have, at the Conference, copies of all overheads and slides used in the presentation of this paper. In addition, examples of installation procedures, audit and test databases, and test and system support documentation will be available.

BIBLIOGRAPHY.

The following are some applicable Codes, Standards Methods and Practices.

ANSI C2 - 1990. *National Electrical Safety Code.*

ANSI/EIA/TIA 571-1991. *Environmental Considerations for Telephone terminals.*

ANSI/NFPA 70 1996. *National Electrical Code.*

ANSI/NFPA 780-1992. *Lightning Protection Code.*

ANSI T1.311-1991. *American National Standard for Telecommunications - DC Power Systems - Telecommunications Environment Protection.* (Update in progress - 1996.)

ANSI T1.313-199X. *American National Standard for Telecommunications - Electrical Protection for Telecommunications Central Offices and Similar Type Facilities.* (Update in progress.)

Building Industry Consulting Service International (BICSI). *Telecommunications Distribution Methods Manual, 1996.*

Building Industry Consulting Service International (BICSI). *Cabling Installation Manual. 1997*

CFR Title 29, Part 1910. *Occupational Safety and Health Standards (OSHA).*

IEEE Standard 142-1991. *IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems.* (The IEEE Green Book.)

IEEE Standard 446-1987. *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications.* (The IEEE Orange Book.)

IEEE Standard 450-1995. *IEEE Recommended Practice for Maintenance, Testing and Replacement of Vented Lead-Acid Batteries for Stationary Applications.*

IEEE Standard 1100-1992. *Recommended Practice for Powering and Grounding Sensitive Electronic Equipment in Industrial and Commercial Power Systems.* (The IEEE Emerald Book. Update in Progress - 1996)

IEEE Standard 1184-1994. *IEEE Guide for the Selection and Sizing of Batteries for Uninterruptible Power Systems.*

IEEE Standard 1187-1996. *IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications.*

IEEE Standard P1188-199X. *IEEE Recommended Practice for Maintenance, Testing and Replacement of Valve-Regulated Lead-Acid Batteries for Stationary Applications.*

IEEE Standard 1189-1996. *IEEE Guide for Selection of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications.*

UL 96A-1882. *Installation Requirements for Lightning Protection Systems.*

UL 924. *Standard for Emergency Lighting and Power Equipment.*

Uniform Building Code (UBC). International Conference of Building Officials, 5360 South Workman Mill Road, Whittier, CA. 90601.

Notes on Bibliography.

- The above documents are being constantly updated and new documents are being created. It is the responsibility of the user to ensure that the latest information is being used.
- Documents may be obtained through PowerConsult (301 694 9673) or direct from the issuing authority.
- Abbreviations and Addresses

ANSI.	American National Standards Institute 11 West 42nd Street, New York, NY 10036
BICSI.	Building Industry Consulting Service International 10500 University Center Drive, Suite 100, Tampa, FL 33612-6415
CFR.	Code of Federal Regulations
EIA	Electronic Industries Association 2001 Pennsylvania Avenue, NW, Suite 800, Washington, DC 20006-1813
IEEE.	Institute of Electrical and Electronics Engineers 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331
NFPA	National Fire Protection Association 1 Batterymarch Park, Quincy, MA 02269
TIA	Telecommunications Industry Association 2001 Pennsylvania Avenue, NW, Suite 800, Washington, DC 20006-1813
UL	Underwriters Laboratories 1285 Walt Whitman Road, Melville, L.I. NY 11747