MONITORING

OF

VRLA BATTERIES

GUIDELINES

No. GL/BAT-04/02 MAR 2007

This document supersedes the previous document " Monitoring of VRLA Batteries Guidelines No. GL/BAT- 03/01JUN 2003"

TELECOMMUNICATION ENGINEERING CENTRE
KHURSHIDLAL BHAWAN, JANPATH,
NEW DELHI-110001
(INDIA)

HISTORY SHEET

Date	Issued	Remarks
JUNE 2003	GL/BAT-03/01JUN 2003 Monitoring of VRLA Batteries Guidelines	First issue
MARCH 2007	GL/BAT-04/02 MAR 2007 Monitoring of VRLA Batteries Guidelines	Second issue To incorporate major changes in technology part and addition of problems and solutions.

CONTENTS :

References

1. BIS 1651 : Stationary cells and batteries.

2. BIS 1554 with amendment-I (1994) : Fire Retardant Cables.

3. GR/BAT-01/03 MAR 2004 with amendments if any : VRLA Batteries

4. GR/BAT-02/02 MAR 2006 with amendments if any : VRLA Batteries for High Rate of Discharge (UPS) Application.

5. GR/BAT-03/01 MAR 2006 Tubular VRLA Batteries based on GEL Technology.

6. GR/SMP-01/05 JAN 2005 with amendments if any : SMPS based Power Plants.

7. Maintenance free Batteries by D Berndt.

8. Battery Reference Book by T.R. Crompton.

9. Modern Battery Technology Edited by Clive D.S. Tuck.

10. Battery Technology Hand-book Edited By H.A. Kiehne.

11. QM-333 : Specification for Environmental Testing of Electronic Equipments for Transmission and Switching use.

12. QM-115 : Quality standard for calculation/verification of MTBF

13. IS 1554 with amendment-1 (June 1994) : Standard for Cables & Wires

14. ITU-T Rec. 0.41 : Psophomeric noise requirements.

PART 1

TECHNICAL REQUIREMENTS

(VRLA BATTERY TECHNOLOGY, PROBLEMS AND SOLUTIONS)

GL No. GL/BAT-04/02 MAR 2007

1.0 Scope

This document covers the basic theory and concept of VRLA Batteries technology. It also covers the necessary guidelines for planning of the Batteries for a given telecom equipment. These guidelines have detailed the facts which shall be taken into consideration while selecting a Battery for a given requirements. It has also given the guidelines for calculating load for a given system. Sample calculation for deciding the load and Batteries have also been incorporated in this document to elaborate the guidelines for the user.

1.1 Introduction

The battery is an important constituent of the Telecom Network for sustaining the trouble free and uninterrupted service to its users. Till 1994, the whole of the Indian Telecom Network relied wholly on Flooded type batteries to provide the necessary power back-up.

In the initial stages of standby power source, flooded flat-pasted type batteries were used in the Indian telecom network. Later on flooded tubular positive plates batteries were used. All these batteries were being procured and tested as per respective IS standard IS-1650. The certification of these batteries was being done by QA wing of DoT (presently BSNL).

Moreover the Conventional lead acid (Flooded type) batteries which were being used in the department were bulky and required a separate battery room with exhaust fans to throw out the acid fumes emitted by these batteries. Flooded batteries can not be transported in charged condition, hence assembly and charging at site is essential. These batteries also require periodical special charging process at comparatively higher voltage of 2.7V/cell (a total voltage of 65 V), also known as boost-charging, to agitate the electrolyte thoroughly to prevent stratification of electrolyte, as well as to reduce sulpahtion of plates. As the telecom equipment can not withstand such a high voltage, the battery under boost-charging and the charger have to be isolated from the exchange equipment. Maintenance of these batteries needs more efforts and is more labour oriented. Moreover, it will be more difficult for the flooded batteries to meet the pollution norms, issued by Ministry of Environment and Forest.

In 1994 the VRLA batteries were introduced in Indian Telecom Network for the first time. Since then, the Department has been procuring VRLA batteries for the purpose. This is because of the fact that these batteries do not require the rigid routine maintenance like periodic topping up, recording SG of each cell and periodic discharge/charge cycles.

VRLA batteries require very little maintenance, that is why they are confused as “maintenance free batteries”. These batteries emit extremely low amount of gases and do not require periodic toping up. Hence, they can be installed in the equipment room itself, thus saving the manpower and long connecting bus-bar or cables. Plates of these batteries have a higher current density, hence have a small size. As these batteries are based on starved electrolyte principal, can be installed in any orientation. All the above characteristics make VRLA batteries ideal stand by power source for Telecom applications.

1.1.1 But these batteries have their own problem and limitation, which require timely and intelligent handling. Some of the constraints are :

Self Discharge : As these batteries are supplied in charged condition. These cells/batteries get discharged of its own on its internal resistance and some localised action within the cells. This is termed as self discharge. Self discharge of these cells/batteries is about 14 percent every four weeks. This fact was clearly indicated in the first version of the GR, issued in August 1994.

Effects : In the initial stages of the introduction of VRLA batteries, it was found that, these battery were kept in storage for very long period of six months and even much higher, which was one of the reason for under par performance of these batteries in the initial stages of introduction.

If these cells/batteries are allowed to remain in this state for a long period of time, say, 3 months or more, the sulphation of the plates starts setting in. More the time it is allowed to remain in this state, more the sulphation gets hard and more it becomes difficult to remove it from cells/batteries.

Recommendation : It is essential that these cells/batteries are commissioned in the least possible time so that self discharge and subsequent sulphation layer is kept to minimum.

To cut down the storage time, TEC in February 1998, requested TC HQ, for issuing necessary guidelines to the field units, to make it direct to site item.

In year 2000 in the second issue of the GR, the manufacturers were made to improve their battery design to ensure :

- To minimise the self-discharge, so that, the cumulative self discharge over a period of 6 months, at an average temperature of 35 degree Celsius is below 50% (for AGM Batteries) or 25% (for GEL Batteries) of its rated capacity. Through this requisition the risk of hard sulphation was reduced a bit. Even than it is essential that the battery is commissioned with in the shortest possible time and a storage period of more than three months is avoided.

1.1.2 **Temperature Effect :** Batteries are very temperature sensitive. The kinetics of these batteries are temperature dependent. The chemical reaction increases/decreases in geometric progression which the increases or decrease in temperature. The Temperature in case of VRLA

Batteries is significant because of limited volume of electrolyte which restricts heat conduction. In the light of this fact, the proper temperature is essential for the optimization of battery life. Internationally the batteries are design at 25 deg Celsius or 27 deg Celsius. The recombination of gases within a VRLA cell can only take place at a certain rate. If the rate is exceeded, gas pressure will built up beyond the safety valve level, and gases/water will be vented out and permanently lost.

The highest float voltage at which a cell still recombine all the gases driven off the plates is approximately 2.30Volts. If the cell temperature increased while holding the voltage constant, the cell would dry out and possibly go into thermal runaway. Thermal runaway leads to a melting down of the jar and under worst- case scenario, will lead to an explosion and fire.

a) **Low Temperature effect :** Battery capacity is diminished at low temperature. Also the charge acceptance decreases with the decrease in temperature. Therefore at low temperatures, a higher float voltage is required to maintain full charge and if charger is not adjusted properly, cell may be undercharged, leading to the problems described under low voltage.

b) **High Temperature effect :** The chemical reaction becomes faster and faster with rise in temperature above the design temperature (27 degree Celsius) and give rise to a chain reaction. High temperature causes loss of life because every 10 deg Celsius rise in operating temperature, the life is cut to half. High temperature also causes gassing, which means dry out and thermal runaway in VRLA cells.

Recommendation :

i) Batteries temperature shall be maintained to such a value that it does effect the life and performance of the battery i.e. the average temperature shall be maintained around the designed temperature at 35°C.

ii) Charging voltage shall be such that it does not contribute to rise in temperature i.e. 2.25V for float and 2.30 for charge.

iii) The charging current to the battery may be restricted to defined limit (0.1C recommended).

iv) A provision shall be made so that the charger voltage shall be regulated as per battery temperature to slow down the battery kinetics. The provision for battery temperature compensation has been made in the Power Plants. It may be ensured that Battery Temperature compensation unit in the power plant is fully functional & all the terminations are in proper place.

v) Though not mandatory, it is preferable that the battery may be installed in controlled environment for longer life and better performance.

1.1.3 **Paralleling of cells unavoidable :** The highest capacity of single cell available for AGM batteries is 1500AH. To achieve the higher capacity paralleling of cell become a Cell module is essential. However paralleling of cell for VRLA batteries based on GEL technology has not been recommended by TEC, because of higher internal resistance of these type of cells. The highest capacity single cell based GEL technology is 3500AH.

Effect : if the cells are not properly matched, premature failure of cell may take place.

Recommendation :

i) Number of paralleling of cell is restricted to four.

ii) For paralleling, cells below 100AH are not permitted.

iii) Cell/Cell module matching for capacity, voltage and Conductance has been made necessary.

1.1.4 **Charging Techniques :** For this a special charging technique is required to ensure that charging does result in temperature rise.

Recommendation :

i) A constant voltage technique with battery path current limited to 0.1C is recommended.

ii) Float and Charge voltages have been recommended as 2.25V as float and 2.30V as charge. Do not resort to fast charging setting higher float/charge voltages.

1.2 **Failure of VRLA batteries :** Most common reasons for failure of VRLA batteries are :

1.2.1 **Positive grid corrosion :** Every time battery discharges, PbO_2 of the +ve plate gets converted into $PbSO_4$ there is a large increase in its volume, which puts pressure on the paste. Deeper the discharged, more is the increase in the volume of the paste of the positive plate and more is the pressure on the grid.

During charge the paste of the +ve gets converter back into PbO_2 The paste gets contracted.

This expansion and contraction results in loosening of the active material in the grid, over a period of time. This results in loss of contact of the active material with the +ve plate and increase in the cell resistance. This is a gradual process and under normal circumstances is a sign of ageing, which shall only take place when the battery has lived its stipulated life.

In addition to ageing there are other factors which accelerate the process and lead to premature ageing. Some of them are :

1. Larger number of charge/discharge cycles faster the ageing process.

2. Deep Discharge, deeper the discharge faster the ageing.

3. Fast rate of Charging.

4. Fast rate of Discharging.

Corrosion is un-recoverable and indicates the end of cell life.

1.2.2 **Sulphation :** Sulphation of the cells plates due to prolonged under charge, overcharge or prolonged storage may also increases the cell resistance.

This is a recoverable damage unless it is hard enough to remove and can be recovered by careful and controlled charging of the cell. In case the sulphation is soft (not very thick), the same may be recovered by charging the cell along with the battery.

The medium type of sulphation can also be removed by prolonged charging, which may be complete or part depending on hardness of the sulphation.

In both the above cases a few charge/discharge cycles are required for the optimum recovery.

This may be achieved by cycling the cell inside the battery or removing the cell from battery bank and reconditioning, special treatment of charging etc. at the factory by the manufacturer at his premises.

Some times sulphation becomes too hard to overcome. In such a case cell is supposed to be damaged beyond repair.

1.2.3 **Dry out (loss electrolyte) :** There is a misconception that these batteries are fully sealed and no escape of gasses take place. However, the gasses escape through the safety valve to maintain the pressure within cells in prescribed limits and therefore, most common mode of failure of the cell/battery is dry out. This may happen due the excessive escape of gasses from the cell, which leaves the cell with little or no electrolyte. This may happen due to :

a) Fast charging

b) Operation of the battery at a very high temperature

c) Leakage through cracks in the container or sealing.

The indications for above failure are :

a) The first indication for the failure is increase in the internal resistance of the cell or resistance of the battery.

b) Some times the increase in resistance of the battery may not be an indication of the failure of cell or the battery because it may be due to rusted terminals, loose connection etc., this, therefore is very essential that it shall be checked periodically that neither the terminal is rusted or the terminal is loose(for this it shall be ensured that the torque of the terminal is as per manufacturers' instructions. Because, if allowed to remain loose may cause premature failure of the cell/battery.

1.2.4 **Abrupt Failure :** Due to lack of proper monitoring schedule, the cells with high resistance are not deducted in time. In such cases, when the battery is put on load, it fails to take the load. The two main reasons in such cases are :

a) Improper or Loose inter-cell connections : In case the inter-cell connectors are under rated will get excessively heated and may affect the sealing, resulting in to cracks, which in turn lead to escape of gasses and dry out.

b) Increase in the internal resistance of the cell/cells : This may be caused by sulphation or corroding of the plates, fusing or terminals. Abrupt failure will only occur, when the corroding will get very severe i.e. at the verge of breaking.

1.2.5 **Low capacity Failure :** This failure may mainly be attributed to ageing. As the battery ages due to any reason it starts loosing its capacity. If the battery capacity fall below the 80% of its original capacity, it is presumed to have lived its life. Ageing is very slow process in initial stages of decay and gains speed only when it nears 80% of its rated value. If the capacity of any cell/battery is approaching it requires immediate replacement.

It may be mentioned here that both of the above Abrupt and Low capacity failures can be detected, well in advance (unless the cells cracks or sealing gets open due to sustained high terminal temperature), by observing a few indicators, which can alarm well in advance about the failure tendency in a cell or the battery, because decaying of cell or battery is a gradual process and can be detected much in advance.

1.2.6 **Thermal Runaway :** Batteries are very temperature sensitive. The chemical reaction increases/decreases in geometric progression with the increases or decrease in temperature. The Temperature in case of VRLA Batteries is significant because of limited volume of electrolyte which restricts heat conduction. In the light of this fact, the proper temperature is essential for the optimization of battery life. The recombination of gases within a VRLA cell can only take place at a certain rate. If the rate is exceeded, gas pressure will built up beyond the safety valve level, and gases/water will be vented out and permanently lost.

The highest float voltage at which a cell still recombine all the gases driven off the plates is approximately 2.30Volts. If the cell temperature increased while holding the voltage constant, the cell would dry out and possibly go into thermal runaway. Thermal runaway leads to a melting down of the jar and under worst- case scenario, will lead to an explosion and fire.

In the initial stage of VRLA battery development of thermal runaway was considered one of the failure mode, but in India it has not been observed till date and moreover at present it is not considered failure mode. Thermal runaway is calliopes of the battery due to very very high temperature developed inside the battery.

Recommendation :

i) The SMPS Power plants are fully compatible to prevent any excessive temperature in the battery by the features Battery path current limiting, Temperature compensation of the battery, High voltage cut-off and Precise voltage set in the Power Plant.

ii) The user shall ensure that all the above features of SMPS Power Plants are fully functional and properly set.

iii) The battery room shall be employed with the natural air convection (ventilated room) and exhaust fan.

iv) The user shall ensure that the ambient temperature of the battery room has been reduced by employing the natural air convection (ventilated room) with exhaust fan.

1.3 **Factors leading to the premature failure and affecting the life & performance of the battery :** Some of the common factors which affect the premature failure and affecting the life & performance of the battery are :

a) Battery discharge

b) Improper Charging

c) No Temperature control

d) Cell Matching

e) Storage of VRLA Batteries

f) Improper installation

g) Manufacturer Problems

h) Operational/Maintenance issues.

1.3.1 Battery Discharge :

1.3.1.1 Deep discharge of the battery : It is a universal fact that deeper the battery is discharged lesser the life of the battery we get. Moreover it is not recommended to discharge the battery beyond 80% of its rated capacity as it affects the expected life of the battery severely. This can be understood by the fact that an exchange battery when discharged to 20% of its rated capacity, may give up to 3000 such cycles. Same battery when discharged to 50% of its rated capacity it may give about 1800 such cycles and will give only 1400 cycles if discharged to 80% of its capacity. The same battery if discharged to its full rated capacity may only give about 600 such cycles only.

Recommendations : The battery shall not be allowed to discharge beyond 80% of its rated capacity.

1.3.1.2 Frequent discharge or Excessive cycles : As already explained under the heading Grid corrosion, the cycling affects the life of the cell/battery.

Under ideal conditions i.e. moderate ambient temperature (10°C to 35°C), Charging not faster than C/10 rate, and compatible charger a telephone exchange battery, on true float may give about 15 years of its service life, The same battery in cyclic discharge application to 80% DOD (Depth of discharge) will give only 1400 cycles i.e. Four year approximately. The battery application in Indian Telecom Network is neither of the two extreme categories. So more the deep discharge cycles/year, lesser the expected life of the battery.

Recommendations : The battery shall not be allowed to discharge beyond 80% of its rated capacity. Each & every battery discharge shall be properly logged. This will help to have a good idea about the health and remaining life of the battery.

1.3.1.3 Discharging of Batteries at faster rate : The faster the rate of discharge of a battery lower is its expected life for example discharging battery at C/1 rate of discharge will give just half the number of DOD cycles than the battery which is discharged at C/8 or C/10 rate of discharge.

Recommendations :

i) The exchange/transmission & similar application batteries shall be so chosen that they are not allowed to discharge faster than C/6.

ii) Where faster discharge(C/0.5 to C/5) is an essential requirement, as in the case of UPS systems etc., the battery may be planned with the lower expected life as per the rate of discharge. The battery for high rate of discharge application No. GR/BAT-02/02 MAR 2006 only be used in such cases.

1.3.*2* Improper Charging :

VRLA batteries, being starved electrolyte type are more sensitive to temperature. The charge rate is voltage dependent, charge rate also depends on temperature of the electrolyte. Temperature on the other hand also depends on the charging voltage. It is clear that all the three parameters are interdependent. It becomes very essential that proper balance between three is achieved. Therefore, these batteries are required to be charged at precise voltage to prevent the overcharging or under charging of the battery. Moreover the open circuit of AGM and GEL VRLA batteries is higher (2.11 to 2.17V) than conventional flooded load acid batteries (2.01 to 2.07V), hence the power plant designed for flooded batteries are not suitable for AGM and GEL VRLA batteries.

1.3.2.1 Under Charged Battery : Under- charging leads to sulphate crystal formation on the plates. In case sufficient current is not allowed to flow through it the sulphation gets harder and harder, consequently it becomes difficult to break such sulphation. This will lead to loss of active material from the negative plate.

In case the battery is kept in under- charged condition for a long time it loses its rated capacity due to sulphation. In case the battery is kept under charged for a very long duration, sulphation may become hard and difficult to recoverable battery.

Recommendations :

i) Ensure that battery is not allowed to remain under- charged.

ii) Use the power plant which is compatible with VRLA batteries & has enough capacity to take care of load and battery at C/10 rate of charge.

iii) Set the float & charge voltages as per battery manufacturer’s instructions.

iv) At the time of installation/commissioning of the battery, ensure that the battery, is fully charged before putting on load. Follow manufacturer’s guidelines in this regard.

1.3.2.2 Over- Charging of Batteries : Over- charging causes excessive gassing of hydrogen and oxygen. This will lead to the frequent opening of the valve to release the internal pressure and consequent result in the long run is drying out. It will also increase the temperature of the cell, which is not desired for VRLA battery, because high uncontrolled temperature may lead to thermal runway. Moreover excessive charging accelerates grid corrosion.

The charging of VRLA battery at too high rate is another factor which affects its performance & life severely. The two main factors which may cause over- charging are :

i) Higher battery temperature.

ii) Higher float/charge voltage

Recommendations :

i) Use the power plant which is compatible with VRLA batteries.

ii) Float & Charge voltages at 27°C shall be set at 2.25V/cell & 2.3V/cell respectively. Change-over from float to charge & vice-versa is automatic in the SMPS power plants as per TEC GR No GR/SMP-01/05 JAN 2005 with amendments if any.

iii) Ensure that battery temperature compensation in the power plant is fully functional & all the terminations are in proper place.

iv) Do not resort to fast charging by setting higher float/charge voltages.

v) Though not mandatory it is advisable to place the batteries in cooler environment for longer life and better performance.

vi) Set the battery path current in the power plant so that battery path current for each battery in the battery bank is restricted to 10% of the battery capacity.

1.3.3 Temperature affect ***:***

Batteries are very temperature sensitive. The kinetics are temperature dependent. The chemical reaction increases/decreases in geometric progression with the increases or decrease in temperature. The proper temperature will optimize battery life and is especially critical for VRLA Battery. The recombination of gases within a VRLA cell can only take place at a certain rate. If the rate is exceeded, gas pressure will built up beyond the safety valve level, and gases/water will be vented out and permanently lost. At 27 deg Celsius, the highest float voltage at which a cell still recombine all the gases driven off the plates is approximately 2.30Volts. If the cell temperature increased while holding the voltage constant, the cell would dry out and possibly go into thermal runaway. Thermal runaway leads to a melting down of the jar and under worst-case scenario, will lead to an explosion and fire.

a) **Effect of Low Temperature :** Battery capacity is diminished at low temperature. Also the charge acceptance decreases with the decrease in temperature. Therefore at low temperatures, a higher float voltage is required to maintain full charge and if charger is not adjusted properly, cell may be undercharged, leading to the problems described under low voltage.

b) **Effect of High Temperature :** The chemical reaction becomes faster and faster with rise in temperature above the design temperature (27° Celsius) and give rise to a chain reaction. High temperature causes loss of life because every 10° Celsius rise in operating temperature, the life is cut to half. High temperature also causes gassing, which means dry out and thermal runaway in VRLA cells.

Recommendation :

i) Ensure that battery temperature compensation in the power plant is fully functional & all the terminations are in proper place.

ii) Do not resort to fast charging by setting higher float/charge voltages.

iii) Though not mandatory it is advisable to place the batteries in cooler environment for longer life and better performance.

1.3.4 Cell Mismatching :

The conventional cell are available in any capacity up to 5000AH as such the paralleling of these cells to enhance the battery capacity is not required. More over conventional batteries require it charging at higher voltage of 2.7V/cell to prevent stratification. As such a capacity window of 100% to 120% was sufficient to take care of series cell matching in these type of batteries. On the other hand the VRLA Cell capacity has its limitation. Till date the maximum capacity of AGM VRLA Cell in India is 1500AH. To achieve higher capacity battery the cells are connected in parallel. More over charging VRLA batteries, at a rate higher than 2.35V is fatal. However, if the battery manufacturer desires, the battery can be charged up to 2.33V/cell maximum under manual supervision, only after the prier concurrence of the concerned Power Plant supplier. Due to this fact, the cell in a cell module, the cells/modules in a battery and battery strings in parallel working require proper matching to prevent the higher current to be pumped in a cell, module or battery. The battery internal resistance and impedance/conductance varies with capacity, age and even the manufacturing techniques and plate material. As such the cell matching in case of VRLA batteries becomes more important.

Recommendations :

i) It shall be ensured that the cells in a cell modules & cell & cell modules in a battery comply the cell matching requirements of clause 5.11 and 1.3.11 of the GRs for VRLA batteries No. GR/BAT-01/03 MAR 2004 with amendments if any or VRLA batteries for high rate of discharge (UPS) application No. GR/BAT-02/02 MAR 2006, respectively, whichever is applicable.

ii) The cells in a battery shall be connected in the order given by the manufacturer.

iii) The cells of same rating & make shall be used to form a battery.

iv) Battery in the parallel string shall preferably be of same age. If unavoidable, proper impedance/conductance, voltage and capacity matching shall be done before putting them into use.

1.3.5 Storage of VRLA Batteries :

The conventional batteries were formed at site and due to this fact a lot of time was required to install the battery. The VRLA batteries are formed in the factory. At site only interconnection of cells is required to be done, hence these batteries are less time consuming as far as commissioning is concerned.

The VRLA batteries are transported and stored in the fully form condition. It is therefore essential that these batteries are installed and commissioned in the shortest possible time after their dispatch from the factory. This is because all the batteries including VRLA batteries lose their charge due to self discharge. If these batteries are allowed to remain idle for a very long time, say more than six months these battery may get damaged beyond recovery due to sulphation.

Recommendations :

i) VRLA batteries shall be considered a direct- to- site item & it shall be ensured that the battery is commissioned within 6 months of its dispatch.

ii) The battery shall be given freshening charge & ensured that full rated capacity has been recovered before putting it to load/use.

iii) In case of storage period of more than 6 months, the battery capacity shall be fully recovered before putting it to use.

1.3.6 Installation :

At the time of installation itself, the following factors shall be checked so that it does not affect the life and performance of the battery seriously :

i) Manufacturers Installation guidelines.

ii) Cell matching (Voltage, Capacity and Conductance).

iii) Check loose inter- cell connection or with improper torque.

iv) Check to detect damaged terminal, seal or container.

v) Do not put the battery to load without fully recovering its capacity.

1.3.7 Manufacturing Defects :

Common manufacturing defect encountered in the field are :

i) Improper terminal rating.

ii) Faulty seal design.

iii) Improper interconnection

iv) Improper plate formation technique or its fusing.

1.3.8 Operational Problems :

The following conditions should be avoided :

i) Keeping the battery in discharged or nearly discharged condition.

ii) Keeping the battery continuously in undercharged condition.

iii) Over-discharge.

1.3.8.1 Keeping the battery in discharged or nearly discharged condition : A discharged or near fully discharged cell will be damaged and possibility ruined if not charged within 24 to 48 hours. As a battery discharges, the electrolyte starts charging from an acid solution to almost pure water when the battery is fully discharged. Lead dissolves in water and some of the plate material mixes with water to form lead hydrate. Lead hydrate causes the plate surface to turn white and, because it is conductive, it forms a short circuit between the plates, rendering the battery irreversibly damaged.

1.3.8.2 Keeping the battery continuously in undercharged condition : If the battery is kept continuously under charged due to any reason, it may lead to sulphation of the plates and may loose its capacity gradually.

1.3.8.3 Over-discharge : As explained earlier under the heading over- cycling, the over-discharge causes abnormal expansion of the active material in the plates, which leads to permanent damage and also recharging problems. This causes the loosening of active material in the positive plate, leading to loss of contact with the grid. This will lead to increase in resistance and failure of the cell/battery.

1.3.9 Factors that affect the life and performance the battery in Indian Telecom Network :

Indian Telecom Network problems for the maintenance of VRLA batteries are similar any other developing tropical country. Some of the major problems which require solution are :

1. Erratic power supply conditions.

2. Comparatively high working temperature.

1.3.9.1 Erratic Power Supply conditions :

This is the major challenge which requires to be handled, as for as telecom network is concerned. In most of the parts of the country either commercial power supply is scarce. It is either available for a very short time (4 to 8 hours a day, that too not continuous) or not available at all. Due to this fact the batteries remain under charge and if there is no alternate source of power, the undercharge condition gets worse and worse. The consequential effect of under charge condition of the battery have already been highlighted earlier. Undercharge condition battery gets sulphated. Longer the period the battery remains undercharge the sulphation gets harder and harder, which in long term becomes difficult to remove. Sulphation affects the life and capacity of the battery very severely.

1.3.9.2 Comparatively High working Temperature : This has been already explain in clause 1.3.3.

1.4 Options for recoupment of battery capacity and their impacts : Various options available for the recoupment of battery capacity and their impacts are as given in ensuing paras.

1.4.1 Fast recoupment i.e. fast rate of charging : It may be mentioned here that whatsoever method we may adopt 90% of the lost capacity of battery will be recovered in even time.

Some of the traditional charging methods adopted for the recoupment of the battery capacity lost during discharge are :

Constant Voltage Charging (CVC) : This is the prevalent method used for charging of VRLA batteries. In this method the charge voltage for the battery is fixed as per the manufacturers instructions. Normally it is 2.3V/cell. After a discharge, in the initial state of charging the battery may draw very heavy current. To prevent the battery form damage, it is very essential that this current shall be restricted to some limit (normally

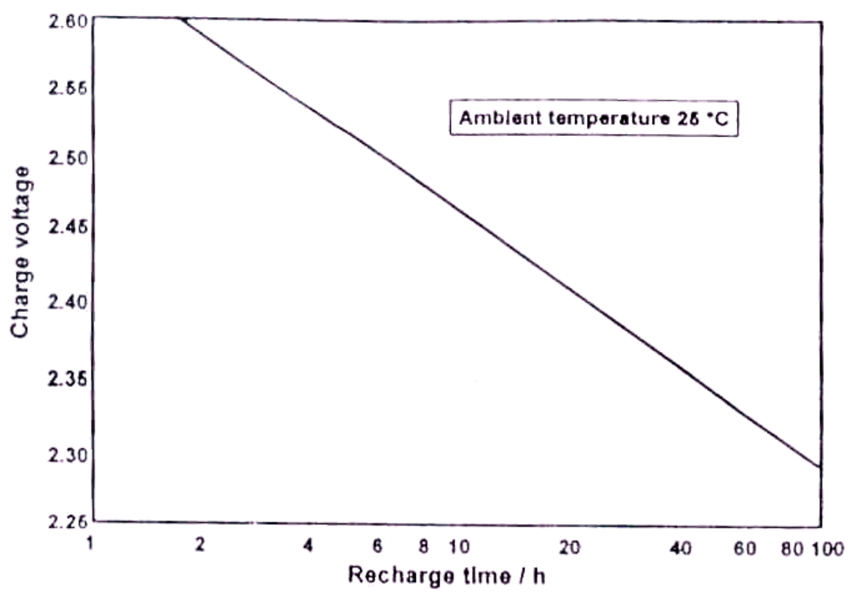
0.1C recommended). Otherwise, this limits may be based on the following considerations :

i) The manufacturer's recommendation.

ii) The charger capacity (the maximum current it can spare for the battery) of the charger. This is the power plant's capacity in excess of the maximum equipment load.

iii) Time during which the recoupment is battery lost capacity is required.

1.4.2 Relationship between charge voltage and recharge time :



1.4.3 Why constant voltage charging is preferred :

i) Precise voltage regulation is possible.

ii) As in this method, the charging current gets reduced, as battery lost charge is recouped. Therefore this method minimise the risk of overcharge. Moreover the current going into the battery is as per battery requirements, charge efficiency of the battery is also improved.

iii) Charge voltage and limiting current can be varied as per the battery charge duration requirements and available charge. Present day SMPS power plants have a provision for automatic dual voltage setting. This is called auto float charge operation. Normally when the battery is fully charged the charger voltage remains in float mode (low voltage). Float voltage is set as per battery manufacturer recommendation (normally 2.25V/cell recommended). When the charge is available after every discharge. SMPS power plants automatically upgrades its voltage to a higher set limit This charge voltage is set as per :

a) Manufacturer's recommendation (safe voltage for the battery).

b) Duration for recoupment : Two major factors that can accelerate the recoupment are :

1. Charging voltage.

2. Charging Current limit. The different combinations that can be adopted for fast charging are :

Recharge time is a function of rate and depth of discharge, recharge voltage maximum charging current, desired state of charge and temperature.

To determine the anticipated recharge time at 27°C the following equation can be used :

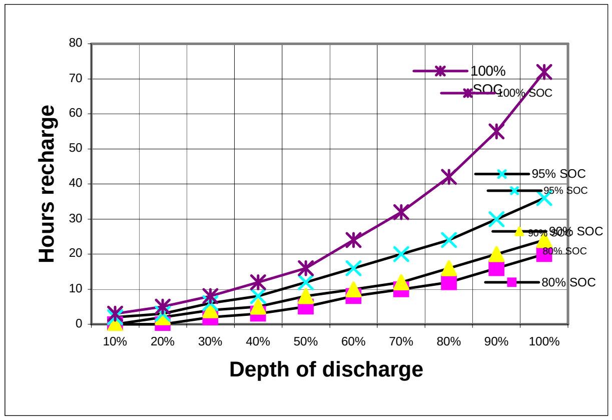
$$\frac{T_{RX\%}}{I_c} = AH_R \times \text{'}K_x\text{'}''$$

Where :

$T_{RX\%}$: Recharge time in hours to X% state of charge (SOC)
AH_R : Ampere hours removed during previous discharge
I_c : Maximum available charging current in ampere's
'K_x' '' : Constant based on approximate maximum charging Current (0.1C, 0.2C, 0.5C and 1.0C) available

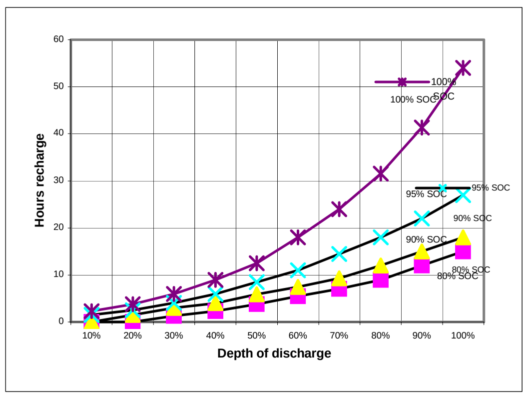
Based on above formula the typical graphs are generated as follows. However, it may be mentioned here that the minimum recharge period for 100% recoupment is minimum 48 hours.

1.4.4 Graph showing Recharge Time (Voltage 2.25V/cell and Current limited to 0.1C) Vs Various Depths of discharge



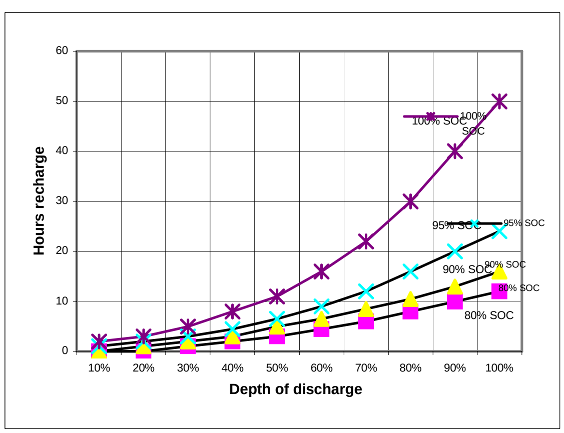
DOD	80% SOC	*90% SOC*	95% SOC	100% SOC
10%	0	0	2	3
20%	0	2	3	5
30%	2	4	6	8
40%	3	5	8	12
50%	5	8	12	16
60%	8	10	16	24
70%	10	12	20	32
80%	12	16	24	42
90%	16	20	30	55
100%	20	24	36	72

1.4.5 Graph showing Recharge Time (Voltage 2.25 V/cell and Current limited to 0.2C) Vs Various Depths of discharge



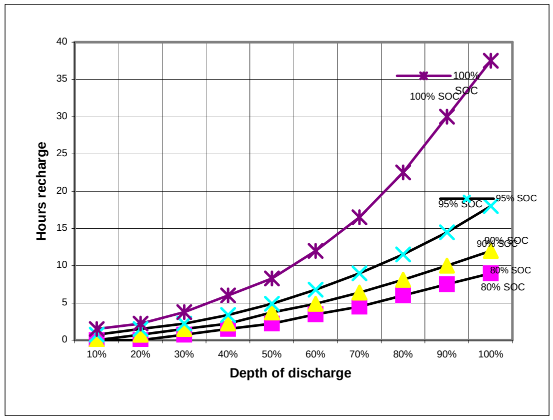
DOD	80% SOC	*90% SOC*	95% SOC	100% SOC
10%	0	0	1.5	2.3
20%	0	1.5	2.5	3.8
30%	1.3	3	4.1	6
40%	2.3	4	6	9
50%	3.8	5.9	8.5	12.5
60%	5.5	7.5	11	18
70%	7.1	9.3	14.5	24
80%	9	12	18	31.5
90%	12	15	22	41.3

1.4.6 Graph showing Recharge Time (Voltage 2.3V/cell and Current limited to 0.1C) Vs Various Depths of discharge



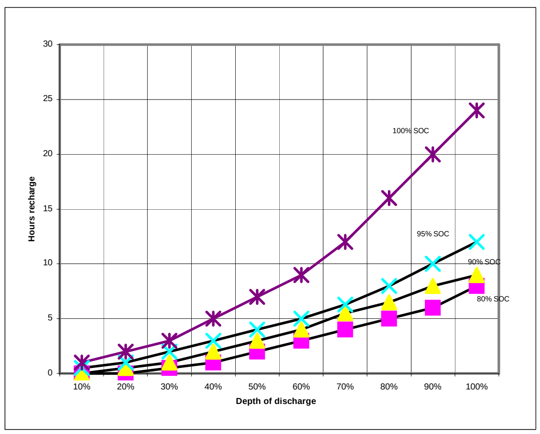
DOD	80% SOC	*90% SOC*	95% SOC	100% SOC
10%	0	0	1	2
20%	0	1	2	3
30%	1	2	3	5
40%	2	3	4.5	8
50%	3	5	6.5	11
60%	4.5	6.5	9	16
70%	6	8.5	12	22
80%	8	10.5	16	30
90%	10	13	20	40
100%	12	16	24	50

1.4.7 Graph showing Recharge Time (Voltage 2.3V/cell and Current limited to 0.2C) Vs Various Depths of discharge



DOD	80% SOC	*90% SOC*	95% SOC	100% SOC
10%	0	0	0.75	1.5
20%	0	0.75	1.5	2.25
30%	0.75	1.5	2.25	3.8
40%	1.5	2.25	3.4	6
50%	2.25	3.75	4.9	8.3
60%	3.5	4.9	6.8	12
70%	4.5	6.4	9	16.5
80%	6	8.1	11.5	22.5
90%	7.5	10	14.5	30
100%	9	12	18	37.5

1.4.8 Graph showing Recharge Time (Voltage 2.35V/cell and Current limited to 0.2C) Vs Various Depths of discharge



DOD	80% SOC	90% SOC	95% SOC	100% SOC
10%	0	0	0.5	1
20%	0	0.5	1	2
30%	0.5	1	2	3
40%	1	2	3	5
50%	2	3	4	7
60%	3	4	5	9
70%	4	6	7	12
80%	5	7	8	18
90%	6	8	10	20
100%	8	9	12	24

1.4.9 Analysis of Graphs and Tables : On the analysis of the graphs and tables for various charging voltages and battery path current limits, it may be observed that by increasing the charging voltage or battery path current or both, the charging time is reduced. It has its own limitations and side effects :

a) **Charging voltage 2.35V/cell or higher :** In case of AGM VRLA batteries 2.35V is considered as a gassing voltage. Excessive gassing may lead to early dry-out. More over it will result in increase in the battery temperature, which is not desirable.

b) **Charging at 2.3V and Charging current 0.2C :** As the cells and battery has some limit to charge acceptance, which depends on the battery design. If higher current for long duration is permitted, it may result in rise in the cell temperature, which is not desirable. If at all required it shall only be used temperature compensation circuitry fully connected and functional. Moreover this will require the additional FR-FC modules for the charging of the battery. For example if at present 4 modules are required for the charging of the battery, we will require 8 FR-FC modules if battery path current is limited to 0.2C.

1.4.10 **Battery Charging Solution for recoupment :** The most ideal solution for fast recoupment, may be :

a) Increase the Float charge voltages up to 2.27V and 2.33V respectively. This will also help in overcoming polarisation of the +ve plate. Also ensure that these limits are not disturbed.

   Note : These limits can be set, if the battery manufacturer recommends, under manual supervision only after the prier concurrence of the concerned Power Plant supplier.

b) Set the battery path current limit as per the power plant capacity, i.e. available power plant rating minus the equipment load. But in no case it shall be higher than 0.2C.

c) It shall be ensured that the temperature compensation in power plant is fully functional and connected to the battery.

d) Battery shall not be allowed to remain under charge for longer period of times, because it may case sulphation. Idea of mobile DG set for a group of stations may be explored to fully charge the battery periodically, in case the electric supply conditions is such that the battery can not be recouped by AC mains.

e) Use only power plant compatible with VRLA batteries.

f) The battery shall be sized properly so that the autonomy requirements are met with 80% of its rated capacity (50% in the cold regions).

1.5 Monitoring of VRLA Batteries :

1.5.1 No foolproof indicators/tools for knowing and predicting the health and life of the battery has been evolved/devised.

In the initial stages of its inception these batteries were called Maintenance Free Batteries. This terminology gave the impression to the users that these batteries are to be “ installed and forgotten. ” Due to this misconception, no proper attention has been given to these batteries, which has led to failures of these batteries.

The commonly used parameters to keep the tab on the health and life of the Flooded type batteries such as observing the level of electrolyte measured of SG (Specific Gravity) can not be applied to VRLA batteries as they are sealed batteries using starved electrolyte technology.

Since the VRLA batteries were introduced in the Department, the need for some device or method or technique, which could give some idea about the state of charge, expected life and expected residual life of the battery was being felt because it was essential for the service provider to keep himself informed about the state of health of battery and warn him well in advance about the impending failure of the battery for the provision of uninterrupted telecom services to its users.

1.5.2 A large number of techniques/methods have been explored and tried by various agencies in the field. Till date, not a single method/test instrument, capable of foolproof prediction about the impending failure of the battery has been evolved/devised. On the other hand, combining some of them, the state of health & expected residual life of the battery can be predicted more precisely & reliably. Some of the methods/techniques used for the prediction of the state of health & expected residual capacity of the battery are :

a) Periodic physical inspection of each cell of the battery for cracks & leakage etc.

b) Discharge of battery for a short duration say 30 minutes to 1 hour and recording the voltages of each cell in the string.

c) Measurement of a mark deviation (>30%) in the Impedance or conductance of the cell as compared to the one recorded at the time of commissioning. These measurements shall be taken OFF-line as detailed in clause 1.5.2.3.

d) Measurement & recording of cell temperature periodically.

e) Float Voltage of cells & its comparison with the mid point voltage.

f) Float current in fully charged battery.

1.5.2.1 Periodic Physical inspection :

Each cell in the battery string shall be inspected periodically for any damage, crack or leakage. An early detection may help in necessary remedial action to prevent failure of the cell/battery. It shall also be ensured that sealing has not developed any type of deformity.

Recommendation : Physical inspection may preferably be carried out every month and it shall be ensured that the inspection is carried out at least once in every two months.

1.5.2.2 Battery partial discharge test :

This test is the most simple and un-expansive method to detect any sign of impending failure (not the expected residual life) of a cell in a string.

The test discharge tables supplied by the manufacturer with the battery shall be kept at an easily accessible place as this table will be used as a reference.

Every partial test discharge shall be properly recorded for future reference and comparison.

In this test, the battery is put to a test discharge by shutting down the power plant for short duration of 30 minutes, one hour or a duration as decided by the in-charge of the unit, so that 20% (approx.) of the battery is discharged.

This test may be conducted on fully charged battery if it has not been put to load for some time. In case the battery is frequently discharged due to frequent AC mains interruptions, the observation can be recorded during such failures.

The voltage of each cell is recorded periodically during this test.

Any cell showing drift in voltage, in excess of 5%, as compared to the voltages of other cells in the battery, it shall be put to further scrutiny.

By comparing this discharge voltages with the initial voltages we may have some idea about the loss of capacity of the cell and battery.

Recommended Meter : Digital Volt meter shall be capable to read three place decimal with accuracy 1 mV.

1.5.2.3 Conductance Measurement :

Though a large number of test instruments are available for measurement of impedance & conductance but most of them are with poor reliability & accuracy. More over these measurements are required to be carried in OFF Line (when the charger is ‘OFF” and battery is on float). In these cases analog meters become more unreliable because of noise induced by Telecom equipment & power plant.

It is also true that there is little data available on the long term trends of cell impedance/conductance.

Different cells from different manufacturers & of different lots from the same manufacturers will have different Impedance/conductance.

Normally change in Impedance/conductance change less than 30% indicates the health state of cell/battery & more than 40%, the imminent failure of the battery/cell.

In the range 30% to 40%, it is very critical & difficult to predict the state of cell/battery because there is uncertainty of 5% in the measurement and also the reference impedance/conductance is also known to be within 5%.

There are a large number of meters available in the market with or without computer interface.

The value impedance/conductance of each cell given in impedance/ conductance table provided by the manufacturers shall be verified at the time of commissioning and shall be taken as the reference.

The readings may taken at the time of partial test discharge and scrutinised for deviations. In case deviations in any of the cell are observed outside the specified limits of 30%, it shall be put to further investigation.

Recommended Meter: Digital Impedance/Conductance meter with online accuracy 2% and resolution of 3 place of decimal. Its power drain from the cell/battery during test shall not be more than 0.5A.

1.5.2.4 Temperature of the cell/battery & life of the battery

Temperature at which the battery works is an other important factor which affects the life of the battery seriously. The chemical reaction in the cell depends mainly on two factor the charging voltage and its temperature. Higher the temperature, faster is the reaction in the cell. It is also true that faster the reaction higher is the active material shedding, gassing and grid corrosion. The gassing may onset the thermal runaway.

It is also an important factor that the cell temperature and battery deterioration is not a linear but an Arrhenius relation (every 10 degree rise in temperature double the chemical reaction). In the light of this fact it is essential to effectively monitor and control the temperature of the cell/battery.

The SMPS power plants as per GR No. GR/SMP-01/05 JAN 2005 with amendments if any has taken care of the battery to some extent by slowing down the chemical reaction by reducing the charger voltage. But this has the following limitations :

i) It monitors the temperature of the pilot cell.

ii) It simply slows down the chemical reaction by pulling down the charger voltage, without creating an alarm.

It is important to measure the individual cells temperature periodically and keep a record for study and analysis for prediction of the residual life of the battery. Temperature sensors with computer interface are available for the purpose.

Recommended Meter : Thermometers/temperature sensor/probes shall be capable of reading in steps of 0.1° C and of accuracy of 0.1° C.

1.5.2.5 Float Voltage :

Float voltage is another important parameter on which the life & performance of the battery depends. Though SMPS power plant as per TEC GR No. GR/SMP-01/05 JAN 2005 with amendments if any provide for temperature compensation of the battery, but the initial setting of the battery float voltage is very essential. The float voltage shall be so set the corresponding voltage at 27 degree Centigrade shall be 2.25V/cell for float voltage and 2.3V/cell for charge voltage taking the adjustment factor @ 3mV/cell/degree centigrade.

Moreover in case floated parallel strings, the float current in each string will depend on the internal resistance of the string. Therefore it is essential to ensure that the parallel strings are properly matched for conductance and resistance.

1.5.2.5.1 Float voltage Monitoring :

1.5.2.5.1.1 Mid-point Voltage Measurement :

Some battery monitors measure the midpoint voltage of each battery string. This is very simple approach to detect voltage deviations within string. In this method monitor will create an alarm when there is a sufficient imbalance in the two half string voltage. This method has its own limitations because as the system voltage increases the midpoint monitoring loses its resolution and as such also loses its ability to discern a deviant cell.

1.5.2.5.1.2 Individual cell Monitoring :

To achieve the optimum benefit of voltage monitoring it is essential that the voltage monitoring is done at cell level. In this technique the voltage of each cell is measured and deviation in any of the cell can be detected quickly and easily and remedial action required can be taken.

Though the power plants as per TEC GR No. GR/SMP-01/05 JAN 2005 with amendments if any do have the provision for cell voltage monitoring but this facility has been incorporated recently in the power plants of some of the International manufacturers & may be incorporated.

Recommended Voltmeter : Digital Voltmeter shall be capable to read three place decimal with accuracy 1 mV.

1.5.2.6 Current Measurements :

Currents for all the three states charge/discharge/float, of battery are important factors affecting and predicting the life and state of health of a battery or a battery in a parallel string.

As the current being drawn by a battery or a battery in the parallel string will depend on the internal resistance and impedance/ conductance of a battery. The battery with lower internal resistance will draw more current and as such faster chemical reaction. In the light of this fact it is important that the batteries in a parallel string draw a current within a specified window/tolerance. It is also the opinion that a fully charged battery shall not draw more than 400mA at 27 degree centigrade, when it is on float, any mark deviation from this value need investigation. A large number of current measuring devices are available. Proper attention shall be given to the requirements while selecting such instruments.

Recommended Meter : Digital meter shall be capable to read three place decimal with accuracy 1 mA.

1.6 Monitoring Schedule : The following Monitoring schedule for VRLA batteries is recommended by TEC :

RECOMMENDNED MONITORING SCHEDULE
FOR
VRLA BATTERIES

Daily	Monthly	Quarterly
Temperature & Voltage of each cell in all the strings	Voltage of each cell during partial test discharge	Conductance measurements
	Float Current Measurements	
	Physical Inspection	

Note: The Batteries can be monitored, for the parameters, as per the procedure given in the respective clauses of this document.

END OF THE PART 1

PART 2

GENERAL REQUIREMENTS

(PLANNING OF VRLA BATTERIES)

GL No. GL/BAT- 04/02 MAR 2007

2.0 Planning of VRLA Batteries

2.1 Battery bank as per Load & Back-up requirements : The battery provides the necessary back-up for the uninterrupted power to the net-work. It is, therefore, essential to ensure that the capacity battery chosen is capable of providing the necessary back-up for which it is chosen. There are some of the primary factors which shall be taken in to account while choosing the capacity of the battery bank. These factors are :

2.1.1 Discharge Application : From the application point of view the batteries may be classified mainly in the two categories :

2.1.1.1 Slow rate of discharge systems : Switching systems large and small, Small Rural exchanges, Transmission systems, Microwave repeater stations etc. where the battery back-up requirements are 6 hours or higher. This battery back-up is normally site specific, depending on the commercial mains supply conditions of the site. The normal practice for battery backup in the Indian Telecom Networks is 6, 12 or 24 hours for Large Switching Systems, Small Switching systems, Microwave repeater stations, small & large Transmissions stations respectively. For SPV Power Systems it is 3 days to 7 days. In these type of systems the batteries are discharged at C/6 rate or slower. For SPV power application the batteries are charged at a rate slower than C/10 rate to economise SPV power system. These type of batteries shall be in compliance of the GR for VRLA batteries and Tubular VRLA batteries based on GEL technology, presently it is as per GR Nos. GR/BAT-01/03 MAR 2004 and GR/BAT-03/01 MAR 2006 with the amendments if any.

2.1.1.2 High rate of discharge systems : These type of batteries can handle higher rate of discharge which can be C/0.5 to C/5 rate depending on the backup requirements of the system to be powered normally these type of batteries are used for UPS systems and other similar high discharge applications. These type of batteries shall be in compliance of the GR for VRLA batteries for high rate of discharge(UPS) applications, presently its number is GR/BAT-02/02 MAR 2006 with amendments if any.

2.1.1.3 While choosing the battery it shall be ensured that the battery selected is suitable for specific application for which it is being procured, considering present and future backup requirements.

2.1.2 Back-up time : The battery bank shall be capable of meeting the load requirements of equipment for specified number of hours. While calculating the battery capacity for a given load & back-up time the following factor are to be taken into consideration :

* The battery shall not be allowed to discharge beyond 80% of its rated capacity because it affects its life severely.

* As the battery is not allowed to discharge beyond 80% of its rated capacity, its capacity, for a given back-up shall be 25% higher than the actual back-up load.

* As the battery capacity is higher for the required rate of discharge because of the above reason, the effective rate of discharge for these batteries will be higher, which will be good for the health and performance of the battery.

For example for four hour back-up the required battery capacity shall be load*4/(80/100) = load*1.25*4 = 5*load & not 4* load. Hence battery will be discharged at C/5 rate instead of C/4 rate of discharge. Same shall be true of other back-up requirements.

2.1.3 **Effective Battery Capacity :** The effective battery capacity for a given rate of discharge shall be as per the tables 1 & 2 as given below depending on the type of battery selected.

2.1.3.1 The VRLA batteries for slow discharge application (Discharge rate C/6 to C/120) GRs No. GR/BAT-01/03 MAR 2004 and GR/BAT-03/01 MAR 2006 with Amendments if any :

Table-1

Rate of Discharge	**Cell**				**Mono-Block**			
	Discharge Current	Capacity expressed as % of C/10 Discharge rate	Discharge time (min) Minutes	End cell voltage	Discharge Current	Capacity expressed as % of C/10 Discharge rate	Discharge time (min) Minutes	End cell voltage
C/3	0.333C	71.7	129	1.74V	0.333C	75.0	135	10.44V
C/4	0.25C	78.2	188	1.74V	0.25C	81.0	195	10.44V
C/5	0.2C	83.3	250	1.75V	0.2C	85.0	255	10.5V
C/6	0.167C	87.3	314	1.75V	0.167C	91.0	328	**10.5V**
C/8	0.125C	95.0	456	1.75V	0.125C	95.0	456	**10.5V**
C/10	0.1C	100-120	600-720	1.75V	0.1C	100-120	600-720	**10.5V**
C/20	0.05C	120.0	1440	1.75V	0.05C	120.0	1440	**10.5V**
C/72	0.014C	130.0	5616	1.75V	0.014C	130.0	5616	**10.5V**
C/120	0.0083C	150.0 **(SPV Application only)**	10800	1.75V	0.0083C	150.0 **(SPV Application only)**	10800	**10.5V**

2.1.3.2 The VRLA batteries for high rate of discharge (UPS) application (Discharge rate C/0.5 to C/5) GR No. GR/BAT-02/02 MAR 2006 :

Table-2

Rate of Discharge	Cell				Mono-Block			
	Discharge Current	Capacity expressed as % of C/5 Discharge rate	Discharge time (min) Minutes	End cell voltage	Discharge Current	Capacity expressed as % of C/5 Discharge rate	Discharge time (min) Minutes	End mono-block voltage
C/0.5	2*C	45	13.5	1.70V	2*C	50	**15**	**10.2V**
C/1	1*C	60	36	1.70V	1*C	65	**39**	**10.2V**
C/2	0.5*C	81	97	1.70V	0.5*C	85	**102**	**10.2V**
C/3	0.33*C	86	155	1.74V	0.33*C	91	**164**	**10.44V**
C/4	0.25*C	95	228	1.75V	0.25*C	96	**231**	**10.5V**
C/5	0.2C	100 - 120	300 - 360	1.75V	0.2C	100- 120	300- 360	10.5V

2.1.3.3 The battery gives rated capacity only at the discharge rate for which it is designed. For example VRLA batteries for Telecom applications as per GRs No. GR/BAT-01/03 MAR 2004 and GR/BAT-03/01 MAR 2006 with amendments if any are designed at C/10 (0.1*C) rate of discharge. The VRLA batteries as per GR No. GR/BAT-02/02 MAR 2006 are designed at C/5 rate of discharge and will give rated capacity only when it is discharged at a discharge current equal to 0.2*C. At all other discharge rates faster than the 10 hours or 5 hour rate as the case may be the battery will deliver less than its rated capacity. Faster the rate of discharge lower the capacity the battery will deliver. The relation between rate of discharge and expected capacity is as given in tables 1& 2 above.

As per the table-1 given above, when the battery is discharged at a current equal to 0.33 times its rated capacity to the end cell voltage of 1.74V/cell, will be only 71.7% of the rated capacity and last for 129 minutes instead of 180 minutes as anticipated. In case the discharge current is equal to 0.2 time its rated capacity the battery will be 83.3% of its rated capacity and last for about 250 minutes instead of 300 minutes and so on.

2.1.4 The temperature at which the battery is to work : At temperature lower than 27° Celsius the capacity of the battery is reduced by 0.5% with every one degree decrease in temperature. This factor is of relevance at places where the ambient temperature goes very low (below 5 degree Celsius) and the rate of discharge is also low, less than C/20.

2.1.5 Charging of battery at rates faster than C/10 is not recommended : As the faster rate of charging is not recommended for VRLA batteries, it is essential that the power plant shall be programmed to ensure that current allowed to battery is restricted to 10% of its rated capacity. For this purpose the proposed battery capacity is essential for battery path current limit setting.

2.2 Sample Calculations for battery bank :

2.2.1 Sample Calculation 1 : Switching System :

(Slow Discharge Application (Battery back-up 6 hours & higher))

Data Required :

a) Load	Present	:	400A …. Say
	Ultimate	:	700A
b) back-up required		:	6 hours
c) Permissible DOD		:	80%
d) Place where the battery is to work		:	Planes of India

Battery Capacity Calculations :

- As the battery is for slow discharge application, the battery shall be in compliance of the GRs No. GR/BAT-01/03 MAR 2004 for VRLA batteries and GR/BAT-03/01 MAR 2006 for Tubular VRLA Batteries based on GEL technology with amendments if any.

- The Battery is expected to deliver the effective capacity of 87.3% of C/6 rate at discharge rate of C/10 as indicated in the given table -1 on page 25.

The required capacity of the battery, considering all the above factors can be calculated as given below :

At present : 400*(6/0.8)/0.873 = 3436.4 AH
Ultimate : 700*(6/0.8)/0.873 = 6013.7 AH say 6000 AH

Where :

- 400 A is the present rated load
- 700 A is the ultimate load
- 6 is the required back up time
- 0.8 is the capacity up to which battery is permitted to discharge
- 0.873 is the expected effective battery capacity at C/6 rate of discharge.

The battery-bank can be formed by selecting available batteries. The solution in this case is : two 2000AH batteries for the present load and additional 2000AH battery can be added at the later stage subjected to compliance of clause 1.3.4 of part 1.

Note : The above mentioned sample calculation for battery-bank requirement can be selected as per nearer available capacity of batteries used in telecom network. The required capacity of the

battery bank can be doubled in the tender by planning cell of service provider, depending up on the field conditions.

2.2.2 Sample Calculation 2 : Computer Terminal :

(High discharge application (Battery back-up 0.5 to 5 hours)

Data Required :

a) Load	Present	: 50A …. Say
	Ultimate	: 80A
b) Back-up required		: 0.5 hours
c) Permissible DOD		: 80%
d) Place where the battery is to work		: Planes of India

Battery Capacity Calculations :

- As the battery is for high discharge application, the battery shall be in compliance of the GR for VRLA batteries for high rate of discharge (UPS) application, No. GR/BAT-02/02 MAR 2006 with amendments if any.

- Battery is expected to deliver the effective capacity 45% at C/0.5 rate of discharge of C/5 as indicated in the given table - 2 on page 26.

The required capacity of the battery, considering all the above factors can be calculated as given below :

At present : 50*(0.5/0.8)/0.45 = 69.44AH
Ultimate : 80*(0.5/0.8)/0.45 = 111.11AH

Where :

- 50A is the present rated load
- 80A is the ultimate load
- 0.5 is the required back up time
- 0.8 is the capacity up to which battery is permitted to discharge
- 0.45 is the expected effective battery capacity at C/0.5 rate of discharge.

The battery-bank can be formed by selecting available batteries. The solution in this case is : one 80AH battery for the present load and additional 80 AH battery can be added at the later stage .

2.3 Disposal of unserviceable Batteries

2.3.1 The unserviceable batteries shall be disposed in accordance with Gazette Notification issued by Ministry of Environment & Forests " Extraordinary Part-II-Section-3-Sub-section(ii) No. 311 issued at New Delhi May 16, 2001"

2.3.2 The batteries shall be sold, for recycling, only to those units registered with the Ministry of Environment & Forests as recyclers possessing environmentally sound management facilities for reprocessing the same.

2.3.3 The list of approved recyclers of used/old batteries is available on the Ministry of Environment & Forests website (URL.www.envfor.nic.in).

END OF THE PART 2

Terminology

Absorption : The taking up or retention of one material or medium by another by chemical or molecular action.

Activated Stand Life : The period of time, at a specified temperature, that a cell/mono-block/battery can be stored in the charged condition before its capacity falls below a specified level.

Activation : The process of making a reserve cell/mono-block/battery function.

Ageing : Permanent loss of capacity due to either repeated use or the passage of time.

Ambient Temperature : The average temperature of the surroundings.

Ampere-Hour (AH) Rating : The rating assigned to the cell/mono-block shall be the capacity expressed in ampere-hours (after correction at 27° Celsius) and stated by manufacturer to be obtainable when the cell/mono-block is discharged at 5 hour rate (C/5) to a final end voltage of 1.75V/cell or 11.5V/mono-block.

Ampere-hour Efficiency : The percentage ratio of the output of the secondary cell or mono-block or battery, measured in ampere-hours, to the input required to restore the initial state of charge, under specified conditions.

Available Capacity : The total capacity, AH or WH, that will be obtained from a cell, mono-block or battery at defined discharge rate and other specified discharge rates or operating conditions.

Capacity : The total number of ampere-hours or watt hours that can be withdrawn from a fully charged cell, mono-block or battery under specified conditions or discharge.

Capacity Fade : Gradual loss of capacity of a secondary battery with cycling.

Capacity Retention : The fraction of the full capacity available from a battery under specified conditions of discharge after it has been stored for a period of time.

Charge Acceptance : Willingness of a battery or cell or mono-block to accept charge. It is affected by cell/mono-block temperature, charge rates and state of charge.

Closed Circuit Voltage (CCV) : The difference in potential between the terminals of a cell/mono-block or battery when it is discharging.

Conditioning : Cycle charging and discharging of a battery to ensure that it is fully formed & fully charged. Sometimes indicated when a battery is first placed in service or returned to service after prolonged storage.

Constant Current Charging : A method of charging the battery using a current having little variation.

Constant Voltage Charging : A method of charging the battery by applying a fixed voltage, and allowing variations in the current. Also called constant potential charge.

Continuous Test : A test in which a cell/mono-block or battery is discharged to a prescribed end-point voltage without interruption.

Counter Electromotive Force : A voltage opposing the applied voltage. Also referred to as Back EMF.

Current Density : The current per unit active area of the surface of an electrode.

Cut-off Voltage : The cell/mono-block or battery voltage at which the discharge is terminated. It is also called end voltage.

Cycle : The discharge and subsequent or preceding charge of a secondary battery such that it is restored to its original conditions.

Cycle Life : The number of cycles under specified conditions which are available from a secondary battery before it fails to meet specified criteria of performance.

Deep Discharge : Withdrawal of at least 80% of the rated capacity of a cell, mono-block or battery.

Depth of Discharge (DOD) : The ratio of the quantity of electricity (usually in ampere-hours) removed from a cell or battery on discharge to its rated capacity.

Efficiency : The ratio of the output of a secondary cell or battery to the input required to restore it to the initial state of charge under specified conditions.

Electrolyte : The medium which provides the ion transport mechanism between the positive and negative electrodes of a cell/mono-block.

End Voltage : The prescribed voltage at which the discharge (or charge, if end-of-charge voltage) of a cell/mono-block or battery may be considered complete (also cut off voltage).

Energy Density : The ratio of the energy available from a cell/mono-block or battery to its volume (WH/V). Also used on a weight basis (WH/Kg).

Fast Charge : A rate of charging which returns full capacity to a rechargeable battery, usually within an hour.

Float Charge : A method of maintaining a cell/mono-block or battery in a charged condition by continuous, long-term constant-voltage charging, at a level sufficient to balance self-discharge.

Gas Recombination : Method of suppressing hydrogen generation by recombining it with oxygen on the negative electrode, as the cell approaches full charge.

Half-Cell : An electrode (either the anode or cathode) immersed in a suitable electrolyte.

Hourly Rate : A discharge rate, in amperes, of a cell/mono-block or battery which will deliver the specified hours of service to a given end voltage.

Internal Resistance : The opposition or resistance to the flow of an electric current within a cell or battery. It is the sum of the ionic and electronic resistances of the cell/mono-block components.

Life : For rechargeable batteries, the duration of satisfactory performance, measured in years float life) or in the number of charge/discharge cycles (cycle life).

Load : The term used to indicate the current drain.

Lot : All batteries of the same type, design and rating, manufactured by the same factory during the same period, using the same process and material, offered for inspection at a time shall constitute a lot.

Maintenance-Free Battery : A secondary battery which does not require periodic "topping up" to maintain electrolyte volume.

Memory Effect : A phenomenon in which a cell, operated in successive cycles to the same, but less than a full, depth of discharge experiences a depression of its discharge voltage and temporarily loses the rest of its capacity at normal voltage levels.

Open-Circuit Voltage (OCV) : The potential or voltage of a cell/mono-block or battery when it is at the surface of the electrode.

Overcharge : The forcing of current through a cell/mono-block after all the active material has been converted to the charged state. In other words, continued charging after 100% state of charge is achieved.

Over discharge : Discharge past the point where the full capacity of the cell/mono-block has been obtained.

Over voltage : The potential difference between the equilibrium potential of an electrode and that of the electrode under an imposed polarisation current.

Oxygen Recombination : The process by which oxygen generated at the +ve plate during charge is reacted at the -ve plate.

Parallel : Term used to describe the interconnection of cells or batteries in which all of the like terminals are connected together. Parallel connections increase the capacity of the resultant battery as follows :

$C_p = n \times C_u$; Where C_p is the resultant capacity, n is the number of cells or batteries connected in parallel & C_u is capacity of the each cell or battery.

Rated Capacity : The number of ampere-hours a cell/mono-block or battery can deliver under specific conditions (rate of discharge, end voltage, temperature): usually the manufacturer's rating.

Recombination : A term used in a sealed cell construction for the process whereby internal pressure is relieved by reaction of oxygen with the negative active material.

Reference Electrode : A specially chosen electrode which has a reproducible potential against which other electrode potentials may be referred.

Self-Discharge : The loss of useful capacity of a cell/mono-block or battery due to internal chemical action (local action).

Semi-Permeable Membrane : A porous film that will pass selected ions.

Separator : An ion permeable, electronically non-conductive, spacer or material which prevents electronic contact between electrodes of opposite polarity in the same cell.

Series : The interconnection of cells/mono-blocks or batteries in such a manner that the positive terminal of the first is connected to the negative terminal of the second, & so on. Series connections increase the voltage of the resultant battery as follows :

$V_s = n \times V_u$ Where V_s is the resultant voltage, n is the number of cells/mono-blocks or batteries connected in series & V_u is voltage of the each cell/mono-block or battery.

Service Life : The period of useful life of a cell/mono-block or battery before a predetermined end-point voltage is reached.

Shelf Life : The duration of storage under specified conditions at the end of which a cell/mono-block or battery still retains the ability to give the specified performance.

Short Circuit Current : The initial value of the current obtained from a cell/mono-block or battery in a circuit of negligible resistance.

Specific Gravity : The specific gravity of a solution is the ratio of the weight of the solution to the weight of an equal volume of water at a specified temperature.

Standby Battery : A battery designed for emergency use in the event of a main power failure.

Starved Electrolyte Cell : A cell containing little or no free fluid electrolyte. This enables gases to reach electrode surfaces during charging and facilitates gas recombination.

State-of-Charge (SOC) : The available capacity in a cell/mono-block or battery expressed as a percentage of rated capacity.

Sulphation : Process occurring in lead batteries that have been stored & allowed to self-discharge for extended periods of time. Large crystals of lead sulphate grow and interfere with function of the active materials.

Thermal Runaway : A condition whereby a cell/mono-block or battery on charge or discharge will overheat and destroy itself through internal heat generation caused by high overcharge or over discharging current or other abusive condition.

Trickle Charge : A charge at a low rate, balancing losses through a local action and/or periodic discharge, to maintain a cell/mono-block or battery in a fully charged condition.

Vent : A normally sealed mechanism which allows for the controlled escape of gases from within a cell/mono-block.

Vented Cell/mono-block : A cell/mono-block design incorporating a vent mechanism to relieve excessive pressure and expel gases that are generated during the operation of the cell/mono-block.

Voltage Delay : Time delay for a cell/mono-block or battery to deliver the required operating voltage after it is placed under load.

Voltage Efficiency : The ratio of average voltage during discharge to average voltage during recharge under specified conditions of charge and discharge.

Watt Hour (WH) Capacity : The quantity of electrical energy measured in watt hours which may be delivered by a cell/mono-block or battery under specified conditions.

Watt Hour (WH) Efficiency : The ratio of the watt hours delivered on discharge of a battery to the watt hours needed to restore it to its original state under specified conditions of charge and discharge. The percentage WH efficiency is the product of AH efficiency & the ratio of average discharge and recharge voltage.

Wet Shelf Life : The period of time that a cell/mono-block or battery can stand in the charged or activated condition before deteriorating below a specified capacity.

Working Voltage : The typical voltage or range of voltage of a cell/mono-block or battery during discharge.

Abbreviations

1	A or Amps	Amperes
2	AC	Alternate Current
3	AH	Ampere Hour
4	BIS	Bureau Of Indian Standards
5	BSNL	Bharat Sanchar Nigam Limited
6	CACT	Component Approval Centre of Telecommunication
7	dB	Decibel
8	dBA	Decibel Absolute
9	DC	Direct Current
10	° C	Degrees Celsius
11	DG	Diesel Generator
12	Emf	Electro motive force
13	FSD	Full Scale Deflection
14	GR	Generic Requirements
15	Hz	Hertz
16	IS	Indian Standards
17	Kg	Kilo Grams
18	LED	Light Emitting Diodes
19	LCD	Liquid Crystal Device
20	mA	mili Amperes
21	MOV	Metal Oxide Varistor
22	MTBF	Mean Time between Failures
23	MTNL	Mahanagar Telephone Nigam Limited
24	ms	Mili seconds
25	mV	Mili Volts
26	PF	Power factor
27	QA	Quality Assurance
28	QM	Quality Manual
29	SMPS	Switch Mode Power Supply
30	T & D	Technical & Development
31	V	Volts
32	VRLA	Valve Regulated Lead Acid
33	WH	Watt Hour

-- END OF THE DOCUMENT --