PRACTICAL APPLICATIONS OF IEEE STD 485-1997

Art Salander
Director, IPS Strategic Accounts
C&D Technologies

INTRODUCTION

The purpose of this paper is to provide a practical explanation of the steps required for a typical sizing of batteries where a complex load profile is involved. For many people, this process can seem both intimidating and daunting. It is not. After a few simple considerations, you will be sizing batteries with speed and accuracy.

Most battery manufacturers provide computer programs to achieve the task of sizing complex load profiles, but these programs are product specific. Unless you have access to several programs from several manufacturers, comparisons must be performed manually.

This paper is an attempt to inform the battery specifier about the features of the sizing **Standard** while gaining a better understanding of the IEEE standard when interpreting either manually prepared or computer generated battery sizing.

First things first, if you want to size batteries using the Standard, please have the most recent copy of the Standard available to you. This paper is not a substitute for the Standard; it will, however, help you to use the Standard more effectively, and it will lead you to the decisions that are the most relevant in performing battery sizing.

This paper and the IEEE Std 485-1997 specifically apply to sizing lead acid battery products. Please refer to those standards which apply to other specific applications or technologies as you desire. Note that a listing of other IEEE sizing standards is shown at the end of this paper. While this paper does not specifically address those standards, many of the suggestions provided here will help you in using those standards, too.

WHY DO WE NEED THIS *STANDARD*?

1) It provides a way for all battery users to offer uniform and consistent battery sizing.
2) The Standard also provides for a reliable way of comparing products and their effectiveness in applications. Comparison is achieved because you will use the same sizing standard regardless of which company has manufactured the battery product.

HOW DOES THE *STANDARD* ACTUALLY WORK?

1) The Standard operates by determining the amount of energy delivered from each positive plate of a battery cell. Simply put, as plates are added together within the cell you have more energy available from that cell.

2) It is important that, when you manually size a battery or check a calculation, you do so using the actual battery cell group determined in the final calculation. This step is extremely important because battery manufacturers' plate groups are created in order to achieve a given product line of battery cells. Just because the plates are the same from one cell model to another, the actual number of plates within the cell affects overall performance.

It is not adequate to evaluate a larger or smaller cell from the product line, but, rather, the exact same one must be used in the final sized assessment. Some may incorrectly assume that the calculation predicting the number of positive plates required, using any given cell example will allow you to extrapolate the cell selection. In fact, you cannot assume that this is at all accurate.

The cell size must always be specifically proven. Factors such as electrolyte concentration/specific gravity and volume of electrolyte within the cell as compared to the number of plates within the cells will affect their performance. Manufacturers' literature will take these factors into account when they publish their discharge data across a product line.

3) ***The Standard, using the Rt method,*** sizes a battery cell by giving you a result that equals the number of positive plates of a type required to support the load. Said number of positive plates would be used to determine a given cell.

4) ***The Standard, using the Kt method,*** sizes a battery cell by giving you a result that equals the ampere hours required to support the load from the given cell.

SIZING METHODOLOGY USING THE "CELL SIZING WORKSHEET" AND THE RT METHOD.

The Rt method calculates capacity by using the amperes per positive plate method to a standard end voltage. This information is determined by all battery manufacturers and is usually provided in the form of discharge tables that are easily understood. I tend to gravitate to the Rt method because the required "S or fan curves", needed to perform the Kt method based on ampere hour capacity and voltage, are not readily available from most manufacturers.

"S or fan curves" when provided will usually contain curves used to calculate performance using either the Rt or Kt method. K factors deal with the percentage of overall AH capacity from a cell at a given voltage. However, while some manufacturers still offer these curves, most do not make this readily available, if at all – so, at least with the Rt method, the information needed to extract the required data is almost always available.

The net result is that the Rt method can be performed using typical manufacturer's discharge tables containing the following information.

- Battery cell designation
- End voltage
- Discharge in amperes based on time

Along with the manufacturer's discharge tables, you need to know the cell's number of positive plates. This information may not be easily evident from the literature. I have found that it is usually coded in within a cell's designation number. To be sure, you should check with each manufacturer for this information, as they are the best source.

WHY CHECK COMPUTER GENERATED BATTERY SIZINGS?

1) Computers cannot offer judgments. A computer program does the math, not the thinking. If you have a complex load profile, you need to ensure that you agree with the final calculation offered.

2) Computers usually cannot interpret and plot the load profile.

3) Check the calculation against your own assessment and the published data.

4) In my experience, computer programs have offered batteries larger than required just because they are programmed to keep rounding up.

UNDERSTANDING LOADS

There are really only two types of load profiles, (a) Simple and (b) Complex.

(a) Simple load profiles - If you have a single load for a fixed duration, that is a simple load and the battery product can be selected directly from the manufacturer's literature. *(Note: Even simple loads should be corrected for aging, temperature, etc. More about those topics, later.)*

(b) Complex load profiles are those where more than a single stage or intensity of load is desired. The complex or multi-stage load profile is the form that the Standard deals with. In complex loads, the battery may be called to deal with all three load types, "continuous, momentary, and random loads".

The complex load profile will have three basic characteristics.

1. Current demand.
2. Duration of current demand.
3. Order of the combination of duration and amount of current demanded.

The above three items need to be listed and then drawn as a bar graph. It is important to note that you may have continuous, momentary and random loads that actually can be added together if they occur at the same time.

Fig 1 - A typical load diagram could look like this. As you can see, many loads overlap and must be added together.

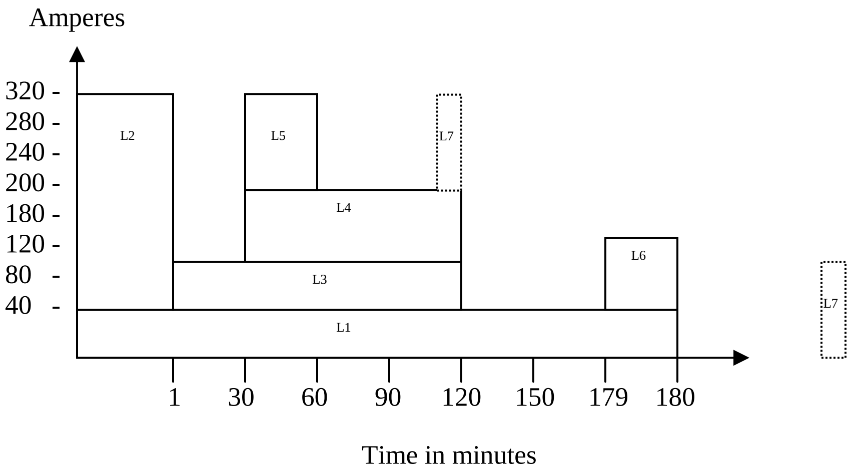
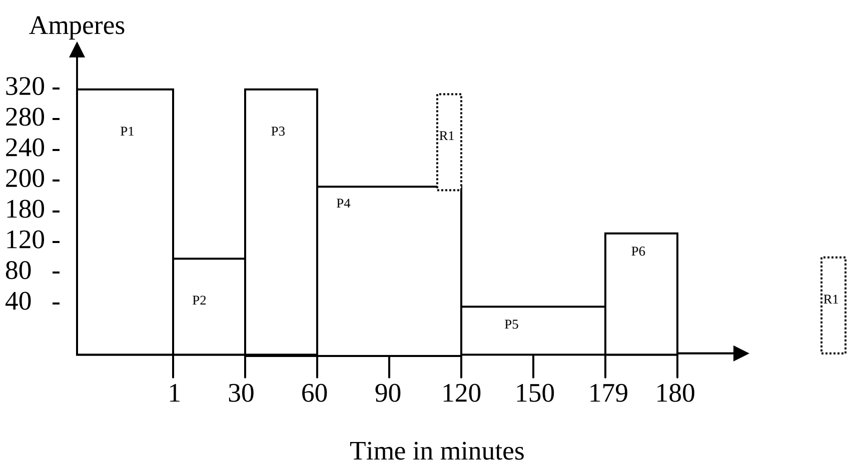


Fig 2 - And then redrawn for sizing to look like this. This diagram provides for an easy way to accommodate the sizing process by listing the discharges as a serial list capable of being used by the sizing person.



Note that in the first drawing, Figure 1, what was 6 loads with one random event becomes 6 periods with one random event in order to be sized using the Standard.

RULES THAT HELP IN DETERMINING AND DRAFTING A LOAD PROFILE.

There are some practical issues when determining this load profile that you may follow in plotting your load profile.

1. No event, for sizing purposes, is ever less than 1 minute. *(1 minute rule applies to lead-acid only.)* This means that if you have several discharges that are less than 1 minute, you can combine them into a single event. As long as these loads are consecutive, only the highest load value needs to be used. Combined, they should add up to one minute or less in duration.

2. Momentary loads, continuous loads, and/or random loads are all added together if they occur at same point in time.

3. Random loads should be added to the worst-case load of the duty cycle. To define the worst case, first size the battery without the random load and then look at the section that defines the battery's size. The end of that section is where the random load goes.

    a. Random loads must be described in terms of their duration and intensity.

    b. It is wrong, as some may assume, to just add them to the end of a profile.

    c. Random loads must be understood by the specifier and applied to the Standard accordingly. It is not enough to say I have a random load, be sure you understand its content and where and when it will and will not occur.

    d. Many times, after careful scrutiny, I have found that stated random loads are not random at all and can be added specifically to a place within the load profile. Further, I have been able to combine several random loads into a single event, effectively.

    e. Random loads are just that – something turns on for some specified time period and draws a specified current at any time within the profile, beginning – end – or anywhere in between. If the "random load" does not meet these criteria – it is not a random load at all!

DETERMINING THE BATTERY SIZE

1. What do we mean by size? There are several answers to this question,

    a. Number of cells? This must be correct in terms of the technology and the applications. End voltages and maximum voltages acceptable are considerations in performing a sizing. Without this information, the wrong data will be applied.

    b. Battery capacity? It is a good idea to guess the capacity if doing the calculations by hand. The standard requires us to pick a sample battery cell as the example when sizing. If you pick one that is not close to the end size required, you will have to repeat the calculation until you get to the correct cell.

    c. Physical dimensions? How much room is available?

    d. Environmental considerations? Ambient temperature, altitude, etc. Is ventilation available? Are people actively in the location? These factors will also help in determining the technology we will choose to use.

2. Temperature corrections or compensation are an important requirement. Whenever you size a battery, the tables used will be stated in terms of a nominal ambient that the tables were created to accommodate. Typically, battery tables are stated for ambient temperatures between 20°C and 25°C, per the manufacturer's data. If your application deviates from this, it is imperative that you correct for temperature as part of the sizing. Correction factors can come from either of two sources: the IEEE Standard itself or the manufacturer's recommendation. My preference is to use the manufacturer's recommendation wherever possible.

Temperature correction in sizing a battery can make all the difference in performance and life expectancy. When evaluating a battery for temperature corrections, be sure you understand the normal use of the product. If a room is temperature controlled all the time and the battery is required only for a relatively short ride through, it is not necessary to correct for abnormal temperatures. However, if a battery spends a major portion of its life at lowered temperatures, correction is required.

3. Design margins are offered as a prediction of system growth and may be very subjective. Design margins provide for the anticipation of system growth. Estimates based on future growth or use of the battery system are the criteria for design margin. Design margins are either based on a judgment or a known factor.

   If you know that the application will not grow, don't add a design margin. A fixed UPS load without any expansion built in does not require additional design margin. However, if you have an application where you know that additional loads may be added, you should try to predict how much the load will increase over time, and then, based on all practical factors, increase the battery size accordingly.

4. Aging factors deal with the anticipated life of the product and the IEEE Std 450-1995 recommendations. In simple terms, it is anticipated that a lead acid battery is considered spent when it degrades to 80% of capacity. Using the IEEE standard, if you desire to ensure 100% at the predicted end of life then, by adding 1.25 to the calculated battery capacity of the newly installed battery, your size selection would then theoretically have 100% capacity at the predicted end of life.

   Other factors can contribute to the prediction of/or practical end of life beyond the normal aging process. Conditions such as elevated ambient temperature, number of discharge cycles, overcharging and poor maintenance will all contribute to shortening overall life.

   Aging factors should not be confused with design margins. Aging factors are designed to ensure that you have a battery at 100% capacity at the anticipated end of life, not to ensure growth as with design margins. Most battery manufacturers list their products in line with this standard in mind, and it is considered routine that, when you reach 80% of overall capacity, the lead acid batteries will degrade quickly and should be replaced immediately. *(Exceptions to this do exist, and the battery manufacturer's claims should take precedence over this consideration if it contradicts it in any way.)*

5. Using the cell sizing worksheet. *(Many people have created Excel spread sheets to do the arithmetic. This is an excellent idea.)*
6.
   a. Use good house keeping and be sure to complete all the information in the heading of the form.

   b. Learn to guesstimate. In every case, you need to estimate what cell type will be used. Make a best guess estimate of what you believe might be the cell type and size to be used.

      i. Perform the sizing first using the "guessed" cell.

      ii. When the calculation determines the final cell type, then use that cell type to prove the calculation.

      iii. It is imperative that you have a complete Cell Sizing Worksheet, with the recommended cell shown for all period evaluations for the sizing to be considered complete and accurate.

CONCLUSION

1) Be sure that you always use the latest version of the Standard.

2) The Standard provides for consistency.

3) The Standard uses two distinct methods for sizing batteries, the Rt and Kt methods. I tend to recommend the Rt method because the required information is more readily available.

4) Sizings that are performed by computer programs should be checked for accuracy.

5) Properly define loads for the purpose of using the Standard**.**

6) You should plot your loads on a bar graph to better determine battery size.

7) Temperature compensation, design margins and ageing factors all contribute to creating an accurate sizing.

8) Using the cell sizing worksheets from the Standard.

REFERENCES

1. IEEE Std 485-1997 (*Revision of IEEE Std 485-1983)* – IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications

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3. IEEE Std 1013-1990 – IEEE Recommended Practice for Sizing Lead-Acid Batteries for Photovoltaic (PV) Systems