Internal Impedance of Batteries

What it is and Why it Works

Batteries are designed and sized to produce a certain amount of current for a given amount of time. Presently, the only method of determining whether the battery will support the load for the needed duration is through capacity testing. But since capacity testing is time consuming, expensive and performed infrequently, there needs to be another method that can be used during the interim. Enter Impedance. Impedance is an electrical test that is capable of determining the state of health of batteries such that battery users can have a sense of reliability without the expense and destruction of frequent capacity tests.

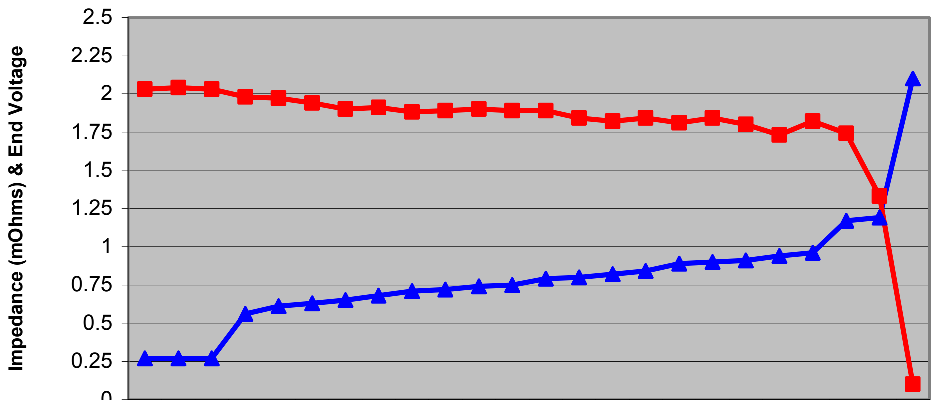
Impedance is a calculation based on Ohm's Law, E=iZ where E is the voltage drop across a resistor (the cell) caused by a current passing through that cell. Impedance is the AC version of resistance. So by applying an AC current signal to the entire string of batteries and measuring the voltage drop of each cell and intercell connector, a very good analysis of the battery's state of health can be determined. Furthermore, since impedance is an AC test, no battery stress or discharge occurs. But one of the most important aspects to impedance is that it can be measured while the battery is on line, reducing risks associated with battery testing.

The test sequence is as follows: apply the AC test signal to the entire string of batteries. (Refer to the manual for specific instructions.) Then with the probes, measure the voltage drop of the cell and the instrument calculates the internal impedance of that cell. Next measure the voltage drop of the intercell connector and again the instrument calculates the intercell connection resistance. Continue until all of the cells and intercell connectors are measured.

The time it takes to measure, say, a 60-cell substation battery including set-up, measuring, analysis and break-down is about 45 minutes. In a telco Central Office with multiple strings, the additional test time per parallel string is about 10-15 minutes. So, it is a fast test that provides reliable information about the battery's state of health between when capacity tests are performed. But what does it tell battery users who rely heavily upon battery back-up systems to support critical loads? Is there a correlation between impedance and battery capacity? The following graph shows why impedance works so well.

In red is the end voltage of each cell after a load test. In blue is the corresponding impedance measured just before the load test. Although, it is not a mathematically perfect correlation, it provides a sufficiently good correlation to show its value to find weak cells.

Ascending Impedance with Corresponding End Voltage



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Imp	0.27	0.27	0.27	0.56	0.61	0.63	0.65	0.68	0.71	0.72	0.74	0.75	0.79	0.8	0.82	0.84	0.89	0.9	0.91	0.94	0.96	1.17	1.19	2.1
End V	2.03	2.04	2.03	1.98	1.97	1.94	1.9	1.91	1.88	1.89	1.9	1.89	1.89	1.84	1.82	1.84	1.81	1.84	1.8	1.73	1.82	1.74	1.33	0.1
Cell #	11	15	16	3	18	22	13	24	10	14	23	20	5	9	6	4	21	8	1	12	2	17	7	19

Impedance finds weak cells because as cells degrade and lose capacity their internal impedance will increase proportionally. The table below indicates approximate changes in impedance that warrant further investigation of cells exhibiting increased impedance.

There are two methods to interpret data, instantaneous and trending. The table below provides general guidelines of action levels based on the percent change of a cell's impedance. Notice that if no previous data were taken, then weak cells can be found based on comparing each cell to the rest of the string as shown in the bar graph which is a standard form printout in the MBITE and BITE 2P. Another way of checking for weak cells when do previous data were taken is to import the test into an Excel® spreadsheet and graph impedance in ascending order in a method we call the "Langan" method named after a retired AVO-Biddle engineer.

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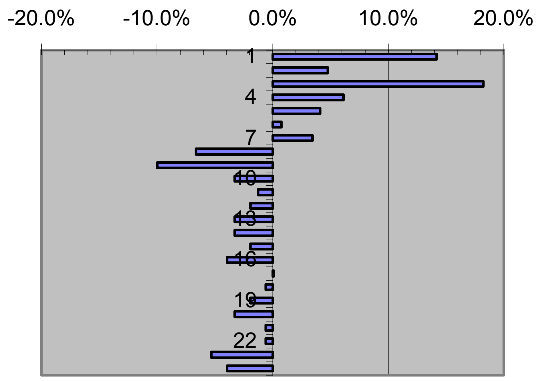
This method is shown as the blue line in the graph above. The weak cells stand out like a sore thumb, so to speak.

Percent Deviation from Average



The other benefit of the printout is that decisions can be made while on site based on the comparison as shown in the bar graph. For example, cell #1 and #3 are considerably higher in impedance than any other cell. This should lead one to further investigation and do a thorough visual inspection and perhaps more tests.

Note: some are led to believe that impedance will reduce the maintenance required on batteries. That may be true if the batteries have been well cared for. But if they have been neglected then impedance will most likely lead to increased maintenance. Impedance is designed to improve battery reliability, not necessarily to reduced maintenance. But in many cases, it can do both.

As good as instantaneous analysis is, the better method is trending starting at the commissioning of the battery. Trending gives details on individual cells that would otherwise not be available. As batteries age, they lose capacity and increase in impedance. If all cells in a string age together (which is not unheard of) then there won't be a cell or two that are significantly above the string average based on instantaneous interpretation. It is then possible that each cell looks good compared to the rest of the string but the entire string needs replacing because it has degraded to the point of not being able to support the load but this is not evident from an instantaneous analysis. So if the string ages together then trending is the only method by which a detailed analysis can be performed on a more frequent basis than capacity testing.

So what does all of this mean for battery users? That the only valid method of determining battery capacity is through occasional capacity testing. But for more reliable state of health evaluation, trending of impedance data taken every three to six months will provide significantly better analysis of whether batteries will support critical loads during outages. Together, capacity testing and impedance may help improve battery reliability.

	Single Test	Multiple Tests*		Trending**	
	% Deviation from String Avg	Cell's % Change from Last Test	Cell's % Change overall	Cell's % Change from Last Test	Cell's % Change overall
Lead-acid, Flooded	5	2	15	2	20
Lead-acid, VRLA, AGM	10	3	30	3	50
Lead-acid, VRLA, Gel	10	3	30	3	50
NiCd, Flooded	15	10	50	10	100
NiCd, Sealed	15	5	35	5	80

* For when data were not taken at installation
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