Utilizing Installed Interface Connections to Enhance Accuracy, Consistency and Efficiency of Ohmic Battery State of Health Testing

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The use of Ohmic measurements (Conductance, Impedance, Resistance) for the determination of battery state of health has been prevalent in telecommunications, UPS, power utility and other applications for decades. The techniques have been proven to be an effective and efficient component of overall battery maintenance by thousands of users worldwide, providing cost and time savings as well as key advance indication of battery degradation for critical applications.

However, like all technologies, even mature and proven ones, there remain some limitations and application challenges that can impact the effectiveness of Ohmic measurements. This is particularly the case when used in the field by inexperienced technicians or in a time constrained manner. Among these limitations is the variation that can occur based upon the point of connection difference from one test sample to the next. Included among these variations is inadvertent test placement on stainless steel hardware that can impede test signals and placement at different locations (strapping vs. post, different post pairs, etc.) from test to test. This variation is, in part, also due to the increased sensitivity of Ohmic measurements that has resulted from enhancements in measurement instruments designed to test a much wider range of battery capacities as well as in demanding electrical environments than in earlier versions. This extreme precision is necessary to capture the full gamut of battery internal electrochemical components over the wide ranging inventory of batteries that are utilized by modern power provisioners. As a result, this precision drives a need for consistency in physical application for the most accurate of comparisons from test interval to test interval, a level of consistency that is sometimes not easily achievable for inexperienced or less-trained technicians or in the face of significant time limitations for the battery maintenance activity.

This paper serves to review a method that can address this increasing need for consistent metallic contact points when using an Ohmic measurement for battery state of health assessments. This method will, as demonstrated in the data presented in this paper, provide a means of true consistency in measurement contact point, increased efficiency in maintenance operation, enhanced technician safety and reduced fatigue for the operator, all resulting in a better battery management program and reducing costs significantly, particularly in large scale users of Ohmic test equipment.

The Method

Traditionally, Ohmic measurements have been taken using a precision instrument that deploys either a clamp set or test probes to make contact with battery positive and negative posts, or if inaccessible, nearby battery Intercell connection hardware. While generally very effective, in some cases, access points can be difficult to reach and this results in inconsistent points of contact from test to test. Also impacting the consistency of these measurements are the aforementioned variables of technician experience and time pressures to complete the work. While the method proposed by this paper is by no means necessary for all installations, it will have significant benefit in many. The method involves the deployment of Kelvin connection test cables (KCTC) to the each battery jar set of terminals, comprised of a Kelvin connection (separating the drive signal and measurement point of the test for accuracy) and positive mating connector that eliminates any human variation from the point of contact. As shown in this picture, these cables can be produced at a fixed length of known resistance based upon battery type to ensure accounting for this aspect in the product calibration process.

The Consistency Benefit

The authors conducted experiments on batteries in use in a common configuration to verify the improved consistency of results provided by the deployment of the KCTC. The experiments consisted of comparing results captured by two different technicians, one experienced and one less so. The technicians tested the batteries with the commonly used method of using test probes, two trials each and then similarly they used the KCTC. The hypothesis developed is that the use of a fixed point of interface to the battery terminals would provide a measurable reduction in variation given the elimination of the natural human inconsistency of movement. Further, it is proposed that improved accessibility of the contact point would reduce the time required to conduct testing and would also mitigate fatigue for the operator given less repetitive strain on the hands during the test process. This also creates an improved safety aspect, as less close contact with the power components of the system and reduced fatigue will diminish the potential for injury.

The Data and Results

Data was collected using two test subjects: one experienced technician with 15 years of battery test history, and one new technician with less than one year. These disparate experience levels were chosen to offset the variable of technician skill in light of the change in test interface. However, this experience level did not factor significantly into the results. In fact, the inexperienced technician made no testing errors with the probe set, while the experienced tech made one error—a probe slip which is further demonstration of the human factor. An anomaly in the available contact area was also identified post-test on jars 9 through 12. The access on these posts were a bit more obscured by stainless steel hardware and as a result registered a much lower reading with the probe set and therefore a higher differential with the KCTC. This serves as another example of the idiosyncrasies that can be found in the field that impact test consistency and can be reduced or eliminated with the deployment of a cable set for use in many applications.

Both technicians tested the same battery system under controlled conditions with the same test instrument and same interfaces. Each was allowed two timed trials with the probe interface and two with the cable connection interface. The data collected is presented in Tables 1, 2 and 3.

Table 1. Technician Test Comparison: Experienced vs. New Technician with Probes

Experienced Technician with Probes								
	Trial 1			Trial 2				
	G	V		G	V		% diff. V	% diff. G
J1	2438	13.593		2450	13.592		0.01%	0.49%
J2	2444	13.657		2456	13.657		0.00%	0.49%
J3	2394	13.714		2388	13.715		0.01%	0.25%
J4	2376	13.796		2382	13.788		0.06%	0.25%
J5	2506	13.605		2518	13.605		0.00%	0.48%
J6	2469	13.641		2475	13.640		0.01%	0.24%
J7	2481	13.661		2481	13.661		0.00%	0.00%
J8	2481	13.872		2481	13.871		0.01%	0.00%
J9	2190	13.633		2190	13.629		0.03%	0.00%
J10	2036	13.608		2030	13.586		0.16%	0.29%
J11	1881	13.568		1640	13.568		0.00%	12.81%
J12	2197	13.818		2227	13.807		0.08%	1.35%
J13	2462	13.581		2469	13.581		0.00%	0.28%
J14	2382	13.616		2388	13.617		0.01%	0.25%
J15	2401	13.727		2401	13.728		0.01%	0.00%
J16	2469	13.832		2469	13.831		0.01%	0.00%
							Std. Dev.	3.15%

New Technician with Probes								
	Trial 1			Trial 2				
	G	V		G	V		% diff. V	% diff. G
J1	2419	13.506		2431	13.567		0.45%	0.49%
J2	2431	13.661		2431	13.663		0.01%	0.00%
J3	2351	13.722		2333	13.723		0.01%	0.77%
J4	2382	13.791		2382	13.798		0.05%	0.00%
J5	2506	13.623		2518	13.623		0.00%	0.48%
J6	2481	13.576		2487	13.586		0.07%	0.24%
J7	2487	13.61		2487	13.624		0.10%	0.00%
J8	2487	13.896		2481	13.902		0.04%	0.24%
J9	2209	13.649		2197	13.636		0.10%	0.54%
J10	2036	13.621		2042	13.603		0.13%	0.29%
J11	1974	13.664		1980	13.569		0.70%	0.30%
J12	2153	13.835		2215	13.866		0.22%	2.80%
J13	2462	13.581		2462	13.582		0.01%	0.00%
J14	2388	13.617		2382	13.617		0.00%	0.25%
J15	2407	13.728		2401	13.73		0.01%	0.25%
J16	2462	13.835		2475	13.83		0.04%	0.53%
							Std.Dev.	0.67%

Table 2. Technician Test Comparison: Experienced vs. New Technician with KCTC Cable

Experienced Technician with Smart Cable

	Trial 1		Trial 2					
	G	V	G	V	% diff. V	% diff. G	% diff. probes to smart cable G- Trial 1	% diff. probes to smart cable G- Trial 2
J1	2444	13.574	2450	13.579	0.04%	0.24%	0.25%	0.00%
J2	2493	13.623	2500	13.635	0.09%	0.28%	1.97%	1.76%
J3	2444	13.640	2450	13.665	0.18%	0.24%	2.05%	2.53%
J4	2363	13.848	2363	13.830	0.13%	0.00%	0.55%	0.80%
J5	2518	13.599	2524	13.599	0.00%	0.24%	0.48%	0.24%
J6	2475	13.647	2475	13.647	0.00%	0.00%	0.24%	0.00%
J7	2512	13.672	2512	13.674	0.01%	0.00%	1.23%	1.23%
J8	2475	13.872	2475	13.867	0.04%	0.00%	0.24%	0.24%
J9	2506	13.666	2512	13.666	0.00%	0.24%	12.61%	12.82%
J10	2333	13.672	2333	13.677	0.04%	0.00%	12.73%	12.99%
J11	1986	13.558	1986	13.560	0.01%	0.00%	5.29%	17.42%
J12	2487	13.871	2493	13.867	0.03%	0.24%	11.66%	10.67%
J13	2469	13.588	2469	13.588	0.00%	0.00%	0.28%	0.00%
J14	2388	13.626	2388	13.629	0.02%	0.00%	0.25%	0.00%
J15	2407	13.688	2413	13.689	0.01%	0.25%	0.25%	0.50%
J16	2462	13.846	2469	13.842	0.03%	0.28%	0.28%	0.00%
					Std. Dev.	0.13%	4.74%	5.93%

New Technician with Smart Cable

	Trial 1		Trial 2					
	G	V	G	V	% diff. V	% diff. G	% diff. probes to smart cable G- Trial 1	% diff. probes to smart cable G- Trial 2
J1	2450	13.584	2450	13.587	0.02%	0.00%	1.27%	0.78%
J2	2500	13.641	2500	13.647	0.04%	0.00%	2.76%	2.76%
J3	2450	13.68	2450	13.69	0.07%	0.00%	4.04%	4.78%
J4	2370	13.813	2370	13.809	0.03%	0.00%	0.51%	0.51%
J5	2524	13.599	2524	13.604	0.04%	0.00%	0.71%	0.24%
J6	2475	13.647	2475	13.651	0.03%	0.00%	0.24%	0.48%
J7	2512	13.672	2512	13.674	0.01%	0.00%	1.00%	1.00%
J8	2475	13.872	2475	13.866	0.04%	0.00%	0.48%	0.24%
J9	2512	13.666	2512	13.668	0.01%	0.00%	12.06%	12.54%
J10	2339	13.677	2339	13.68	0.02%	0.00%	12.95%	12.70%
J11	1986	13.558	1986	13.561	0.02%	0.00%	0.60%	0.30%
J12	2493	13.866	2493	13.866	0.00%	0.00%	13.64%	11.15%
J13	2469	13.589	2469	13.591	0.01%	0.00%	0.28%	0.28%
J14	2388	13.628	2388	13.629	0.01%	0.00%	0.00%	0.25%
J15	2413	13.69	2413	13.696	0.04%	0.00%	0.25%	0.50%
J16	2462	13.843	2462	13.844	0.01%	0.00%	0.00%	0.53%
					Std. Dev.	0.00%	4.94%	4.66%

Table 3. Time Trial Results

Probe Testing

- ✓ Experienced Tech: with probes (1) 3:16
- ✓ New Tech: with probes (4) 4:22
- ✓ Experienced Tech: with probes (2) 3:16
- ✓ New Tech: with probes (3) 3:08

★Average time: 3:30 (210 seconds)

Cable Testing

- ✓ Experienced Tech: with cable (4) 3:06
- ✓ New Tech: with cable (3) 3:01
- ✓ Experienced Tech: with cable (2) 2:59
- ✓ New Tech: with cable (1) 2:56

★Average time: 3:00 (180 seconds)

Initial Conclusions

From the data presented, it is clear that the hypothesis that the use of a fixed point of interface to the battery terminals would provide a measurable reduction in variation and improved accessibility of the contact point would reduce the time required to conduct testing has been proven. Both the experienced technician and the new technician provided results that were more consistent with the KCTC. From a practical standpoint, this results in enhanced perspective on battery state of health and less re-work that comes from inconsistent contact. Perhaps more significant is the increased efficiency in the test process, averaging a near 15% time savings.

Applied across a large user of stationary batteries (such as a telecom operator, battery service operation, etc.) this efficiency improvement could result in tens of thousands of saved Dollars, Euros, Yen, Yuan, etc. far outweighing the cost of the cable installation. Further, this experiment did not account for additional time savings that would be captured from the elimination of technician-driven re-testing based upon probe slipping or moving during the test or other human error that is recognized during the test process and then corrected in the field. It drives for serious consideration of the economic impact of this approach for battery users worldwide.

Going Forward—More Benefits that can be Derived from this Approach

Beyond the demonstrated benefits described above (improved test consistency, increased test process efficiency, reduced technician fatigue and potential for repetitive strain), further development of this concept can offer additional advantages. One such concept in development is the mating of radio frequency identification (RFID) tag into the cabling along with a reader embedded in the mating instrument-side test cable, to make a proposed “Smart Cable™”. Such an approach allows for much more robust capabilities to be incorporated, including adding battery and site identifiers, battery specification and baseline data, captured test data in a read-write format along with date coding and more. This system would even further reduce the human involvement in the test process, virtually eliminating test setup error and the requirement for data input prior to test. It also can be used as a means to absolutely mechanize and ensure that testing is actually completed in the manner described by the operator, eliminating the temptation by busy field techs or outside contractors to “manufacture” data by repeating testing on the same battery or simply copying data sets within reporting systems. From the engagement with the “Smart Cable™” at the site, to the link back to a centralized battery analysis database in a data center, all steps of the process can be controlled and secured.

By this approach, further significant efficiencies will be achieved, allowing manpower to be freed for other key tasks while enhancing and automating the battery testing process and driving accuracy and good decision-making throughout. This advance will be subject of further study.