

AR&D

Automotive Research and Design

Technology and Training Since 1987

Hybrid & Electric Vehicle Transmission Motor Diagnostics

Made Accurate and Easy with the AT33EV

Analysis of transmission/transaxle electric machines (i.e., electric motors and generators) is vital in determining the state of health (SOH) of the electric propulsion system. In this newsletter we will focus on the AT33EV motor circuit analysis tool. It is one of the most powerful tools to accurately assess electric machines. This newsletter will not only explain the AT33EV operating strategy but how it can be used to support new business opportunities for those interested in expanding their services to include hybrid/electric transmissions.

With the cost of transmission repairs ranging from approximately \$3,000 to \$7,000 customers will have serious interest in those that can accurately analyze and diagnose their hybrid/electric transmission and properly repair it at a reasonable cost. When using the AT33EV for a Predictive Maintenance (PM) program to support your fleet or traditional customers, you can confidently communicate electric machine SOH.

There is a quiet change happening in the transmission diagnostic and repair business. It is the quiet sound of electric propulsion and it's coming to you in a transmission now or will in the near future. For about 25 years I have been working with electric propulsion systems and it's exciting to witness the exponential growth of this technology in the automotive transmission market. However, with this growth comes the responsibility to quickly and accurately analyze/diagnose electric transmission symptoms and faults. Analyzing and diagnosing 3-Phase electric machines can be a difficult and a time consuming task without some basic training and proper equipment.

Automotive OEMs do provide on-board diagnostics that can accurately sense electric machine problems that *are at (or) very near a catastrophic level but, problems that are just starting or at a mid-failure level.* The OEM diagnostics are inadequate to determine the root cause if a driveability complaint is an electric machine problem or elsewhere. Scan tool diagnostics are a poor substitute for the diagnostics necessary to properly analyze electric machines.

Electric machines can be analyzed and diagnosed in the field using ohmmeters, milliohmmeters, ammeters, voltmeters, insulation testers, and tachometers. However, these methods use *single dimensional analysis methods* and are inferior and inadequate for *accurate* electric machine analysis/diagnosis. This means that each of these methods (singularly) can possibly identify one type/form of problem. Even so, these failures must be a hard failure (i.e., a failure that is present at all times).

Furthermore, this data cannot be reliably correlated with other data to identify existing or (more importantly) *pending problems or failures.* Also, none of the aforementioned methods can help determine the electric machine Rotor SOH. Therefore, I would not recommend it.

This would be similar to a transmission technician using a 5,000 psi pressure gauge to monitor transmission hydraulic pressures when a 100 psi gauge (more fidelity) is needed to monitor the pressures to identify the root problem! Therefore, *multi-dimensional data acquisition* is preferred by diagnostic professionals for accurate diagnoses.



The 2011 training season is now finished! We would like to thank all of our participants who attended an HEV training course with us this year. We hope to see you again in next year!

See the schedule below for our 2012 training events in Madison, Port Angeles, and Portland.



HEV Tip of the Month

Orange high voltage cables that are damaged (i.e. strands are cut or broken) **CANNOT** be spliced to another cable. Splicing is not considered an approved repair by any automotive manufacturer. Broken cables must be replaced.

Multi-dimensional analysis would be similar to a transmission technician using multiple pressure taps and gauges to monitor circuit hydraulic pressures, and a scan tool to electrically command the shift and pressure solenoids to acquire all of the data necessary to properly analyze the transmission circuits. Multi-dimensional electric machine analysis means that there will be multiple data types and hundreds of data samples to determine 3-Phase Stator and Rotor SOH to provide a highly confident data analysis.

The Anatomy of Electric Machine Failures

Properly testing electric machines can be a tricky business. However, by using a multi-dimensional analysis and diagnostic strategies it becomes a simple task. Electric machines failure modes can come in many flavors. Whether the problem is a winding turn-to-turn short, winding-to-winding short, phase-to-phase short, phase-to-ground short, an open circuit, leaking/cracked wire insulation, worn Stator slot insulation, weak or cracked Rotor magnets, or broken/cracked Rotor bars each of these can cause a variety of driveability symptoms and failures. All of these failure categories are coupled with the fact that the severity of a failure will degrade over time to a catastrophic failure (possibly taking 1 month to 2 years or more) before it could be identified with single-dimensional methods. The trick is to identify a problem before it is catastrophic to keep you and the customer happy with the repair.

Why is this important? If you're performing a hybrid transmission rebuild and intend to warranty the repair for 3 months or more, it would be important to know the SOH of the electric machines prior to giving the transmission a clean bill of health. This is no different than your medical doctor performing a thorough physical so you'll know of any current or pending physical problems.

OK....So, What is Measuring With Multi-Dimensions?

To provide you with examples of multi-dimensional testing, and how the tests are performed, I'm going to use the ALL TEST Pro® AT33EV (Figure 1) as an example of a high quality electrical analyzer that uses eight dimensions to accurately test an electric machine SOH.



Figure 1. ALL TEST Pro® AT33EV

Some of the measurements include:

- Resistance (dc Ω)
- Impedance (ac Ω)
- Inductance
- Capacitance
- Dissipation Factor
- Phase Angle
- Current-to-Frequency Ratio
- High Voltage Insulation Test
- And other tests.....

The dc Resistance will measure the Stator windings and any high voltage cables connected to the transmission (in milliohms). This unit also uses a low voltage ac waveform and changes amplitudes and frequencies to test all coil end-turn integrity, coil-to-coil winding insulation integrity, Stator slot insulation integrity, ac coil resistance, coil winding and connection contamination, and Rotor magnets/Rotor bar states-of-health.

By using the electrical principles of dc Resistance, Impedance, Inductance, Dissipation Factor, etc., the SOH of the electric machine can accurately be assessed with high confidence. This method of using a combination of ac and dc measurement is the equivalent to testing a vehicle using both stall testing and road testing.



AR&D will be attending the the Automatic Transmission Rebuilders Association Powertrain Expo at the Las Vegas Hilton on October 27-31! Click on the photo above to download a FREE PASS into the Trade Show!

HEV News

[Hybrid Electric Car Battery Pioneer Up for Sale](#)

[How Green is Ford's Cars from Inside and Out?](#)

[New Charging Stations Will Give Electric Vehicles Freedom to Roam](#)

Fuel Update

The average price of unleaded gasoline is \$3.70 per gallon in the United States!

Visit [Gas Buddy](#) to view the current gas prices in your area!



Year 2012 Training Schedule

Let's Do Some Testing

Testing electric machines on or, off the vehicle, uses the same process that takes less than 3 minutes to complete using the following steps:

- For on vehicle testing, ensure that the high voltage system has been properly disabled (see manufacturer procedures). If the transmission is on the bench, and not connected to a high voltage source, this is not necessary.
- If the testing is to be done on the vehicle, it will be necessary to access the transmission 3-Phase electric machine connections at the power inverter (Figure 2).

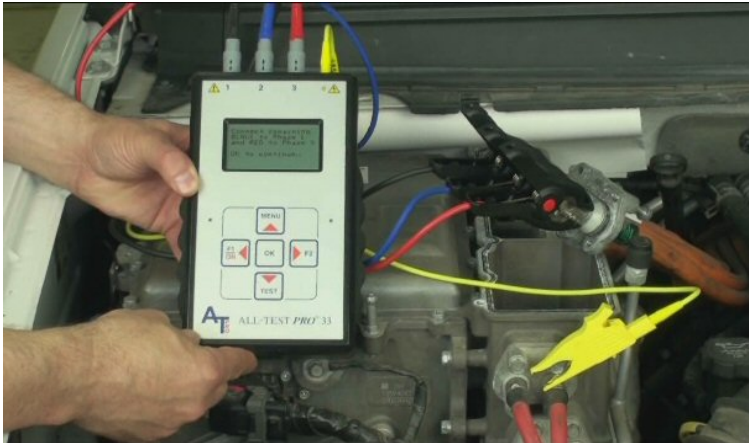


Figure 2. Testing at the vehicle high voltage cables

1. If the power inverter is integral to the transmission (i.e., Ford Escape Hybrid), the power inverter will need some disassembly to gain access to the electric machine connections.
1. Some electric machines can be tested with the transmission fully assembled on the bench (Figure 3) or out of the transmission (Figure 4).

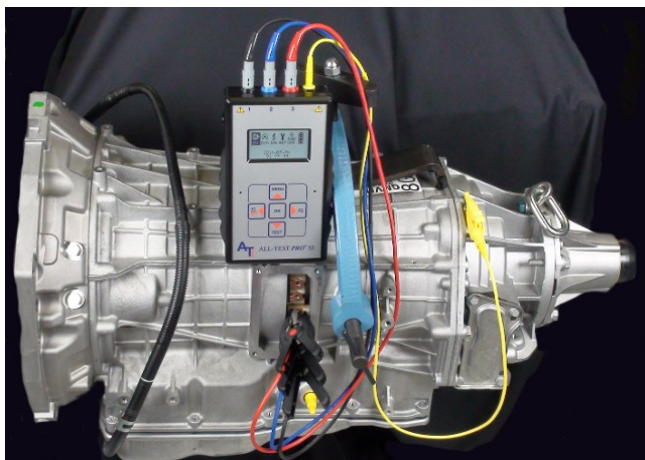


Figure 3. Testing the electric machines with transmission on the bench

Click on the above thumbnail to view the training schedule for the upcoming year.

AR&D has two satellite schools we schedule HEV TTT courses to support summer availability.



Madison Area Technical College

[Click here](#) for more information



Portland Community College

[Click here](#) for more information



We provide you with equipment specifically designed to analyze and diagnose Hybrid and Electric Vehicle Systems.

[Click here](#) for more information.

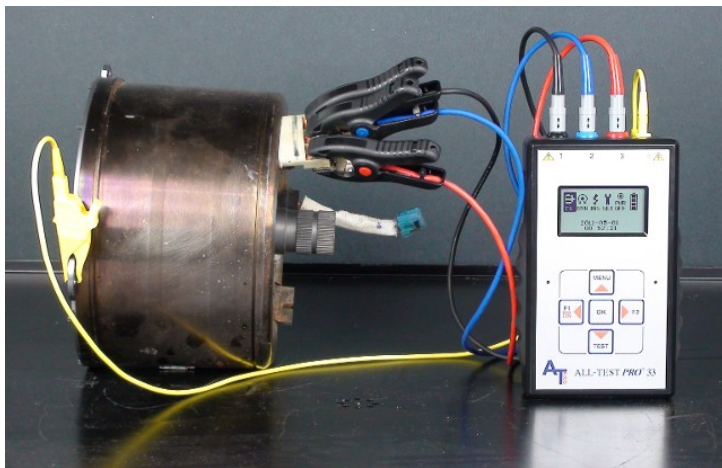


Figure 4. Testing an electric machine out of the transmission

1. The first tests are *Static* (no motor rotation) and performed to determine a baseline measurement of the Stator windings and insulation SOH (i.e., is it beginning to fail, is a failure imminent, or is a hard failure present), see Figure 5.

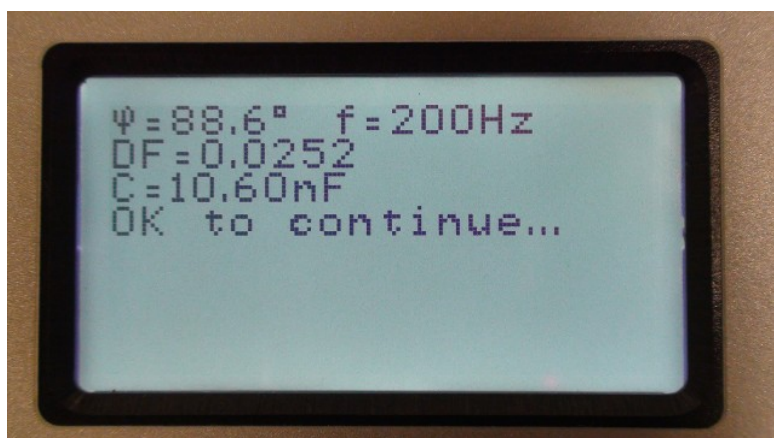


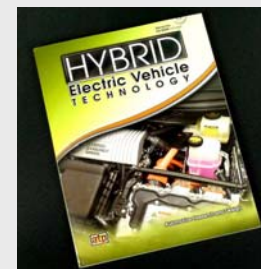
Figure 5. Static testing

Stator winding insulation (polymer materials and enamel, epoxy, or dipped varnish) is actually a *dielectric* function similar to a capacitor. The Stator insulation stores energy and releases it when an ac waveform is transmitted (similar to a capacitor). The unit measures the storage capability of the insulation to find out how much energy the insulation is “leaking” due to cracks, insulation surface or material breakdown, etc. This is similar to inflating a balloon and measuring how much air loss there is due to large holes, pin holes or aged material leakage. Data will be acquired from all three electric machine phases simultaneously and data from each phase is compared against the other two phases to identify any problems.

Static testing will help you determine overall motor SOH (i.e., is it beginning to fail, is a failure imminent, or is a hard failure present). If the insulation is leaking energy or if there is a coil physical failure present the result will be energy losses that ultimately result in (intermittent or continuous) rough motor operation with no DTCs stored in the controller until the failure is catastrophic. The result is the customer can “feel” this in the driveline. As part of Static testing, an insulation test is performed to determine if there is energy leakage from any Stator windings to ground (Figure 6).



The All Test Pro® 33EV is the most powerful tool to analyze and diagnose any 3-phase motor-generator on an a hybrid or electric vehicle. Click on the photo above to learn about its functions and how to use them.



Are you looking to implement HEV curriculum into your class offerings?

[Click here](#) to complete the online request form with our publisher to receive a **complimentary** instructor review copy of our Hybrid Electric Vehicle Technology Student Textbook.

Webinars

To support increased demand in the educational & aftermarket industries, we will be adding webinars to our training products (First Quarter 2012), providing you the opportunity to interact with the instructor. For a listing of webinar topics and descriptions [click here](#).

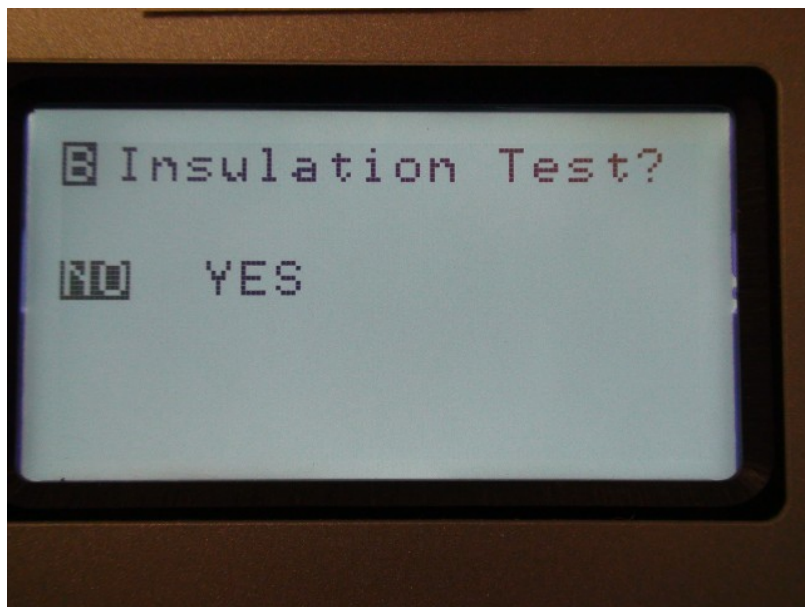


Figure 6. Winding insulation testing

1. After the Static and Insulation testing is completed *Dynamic* Testing (rotating the motor shaft) will be completed. This can be performed if the transmission is in the vehicle or on the bench. This will test the Stator windings and the Rotor (permanent magnet or induction motor). When the Dynamic test is initiated the technician will *slowly* rotate the vehicle tire or (about 10 rpm) or transmission output (spider) gear (about 10 rpm) to capture the multi-dimensional data (Figure 7). The three electric machine phase data results are then compared against each other to identify any problems. Dynamic testing is very similar to completing major engine systems tests (cylinder balance, ignition, and fuel system) to identify any weak or non-functioning cylinders.



Figure 7. Dynamic testing

After the Dynamic test is completed the data and signature test results can be uploaded to a laptop computer. The data and signatures are very easy to interpret. Test data in Figure 8 indicates a shorted Stator winding with a second short in another phase just beginning to start. The Rotor magnets are healthy.

eLearning

Currently, we provide e-Learning training modules through our partner NAPA. For more information [click here](#)



Bookmark us!

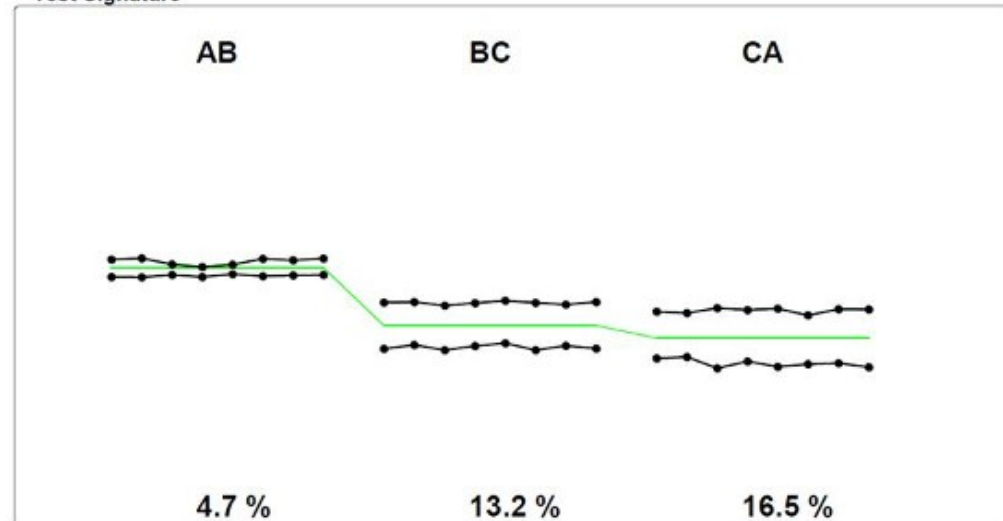
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Test Results

Resistance	✓ OK	37.87 mohm	38.85 mohm	36.78 mohm
Stator	✗ Bad	Reference value 2.06 Test value 1.77 (dev -14.22%)		
Rotor	✓ OK			
Contamination	✓ OK	4.24 %	16.52 nF	
Insulation		-- No reading --		

Test Signature



Summary

Total test time is less than 3 minutes to acquire the data and upload it to the computer. This data will help you determine the electric machine SOH and make an informed decision whether an imminent or future Stator/Rotor replacement is/will be forthcoming, and you don't need to know any motor specs to perform the testing. Also, known good and bad motors can be stored in the AT33EV or on a computer as Reference Test so test data comparisons can be performed quickly. Now, get out there and test those hybrid transmissions to build your business!

*Until next time remember - knowledge is **POWER***



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