ELECTRIC VEHICLE DIAGNOSTIC SYSTEMS, A SIMPLE TASK OR NOT?

Marcel Romijn, BRACE Automotive
Introduction – Setting the stage

Overall Diagnostic System

• OBD Legislation
• (Emissions) Warranty
• Service Information / Right-to-repair
• Cyber Security
• Functional Safety

EV/REX Diagnostic Struggles

• Charging
• Pinpointing
• Safety (and image)

Concluding
Introduction - Setting the stage

FORD Model T Powertrain Controls - Driver
- Throttle
- Ignition advance/retard lever
- Carburetor enrichment lever
- Engine to gearbox clutch
- Reverse clutch
- High/Low range – Neutral clutch

Today's Powertrain Controls - ECU
- Driver kindly asks the ECU
- ECU handles the controls
Powertrain ECU: Driver request and Powertrain “happiness”
- Can you give me 200Nm please?
- Is your Air-Fuel Ratio comfortable?

Electric Powertrain: Driver request only
- Just a torque actuator
- GIVE ME 200Nm NOW!
Introduction - Setting the stage

Conventional
• Vehicle Movement Controls
• Energy Storage Controls
  – Fuel tank, Battery
• Auxiliaries management
• Fuel management
• Air management
• After treatment management

Electric
• Vehicle Movement Controls
• Energy Storage Controls
  – Batteries, Charger
• Energy (flow) management

So electric drivelines are just so much more easy…. (at a glance)

Opens the market to new players at OEM and supplier levels
Overall Diagnostic System

Source: Matthias Weber, Roben Automotive

Remote Diagnostics

Off-board Diagnostics

4G

In-vehicle Diagnostic system

Safety

OBD

Security
Overall Diagnostic System

- Service Information
- Right-to-Repair
- (Emissions) Warranty
- OBD Legislation

- Functional Safety
- ISO 26262
- (EV specific legislation)
- Manufacturing modes
- Service & Repair instructions

In-vehicle Diagnostic System

- NOx Anti-Tampering
- Cyber Security SAE J3061

Remote Diagnostics

Off-board Diagnostics

Source: Matthias Weber, Roben Automotive
Even in a conventional vehicle: many stakeholders

- Luckily: lots of old stuff and processes is carry-over
- Severe focus on emissions & repair; safety is less of an impact

While EV and Range Extender (REX) are treated the same – they are not

- EV has many new systems and additional requirements
- Many new dangers and increased focus on safety
- REX brings in a mixture of the above
- REX builds emissions system on new and EV parts
Diagnostic system clients outside legislator:

- Manufacturing & Logistics
- Service & Repair & Aftermarket
- Emergency Response Teams & Vehicle “Scrapyard”

For EV and REX this is fairly new

- Existing processes and tools often not suitable
- E.g. every organization must know how to disable high-voltage safely
- Imagine stranding with an EV in a third-world country….
- Impact for everyone in the organization and for full vehicle life-time
Not every EV is 100% EV

• Some programs reveal to have a Range-Extender (REX) version also
• Often considered as a side-line “add-on”
  – Comparable to “placing a generator set in the trunk”

• Plans may assume 90% of EV is carry-over to REX
  – In reality adding anything with combustion makes many changes
  – Stop, Drop and Consult… the certification & compliance team
A pure EV is zero-emissions and is free from OBD
• Still “announce” to type-approval authorities
• ~99.9% of the requirements N/A

An REX: most complicated OBD system
• Small failures = increase combustion system time
• Relative emissions increase very high

Re-use of EV components (w/o OBD) in an REX is difficult
• Same component & function; now with full-blown OBD
• Less impact outside the USA
For REX the USA Clean Air Act forces a “emissions warranty”
- Does not exist outside USA

Regardless of which warranty
- EV & REX rely on charger stations – outside vehicle domain
- With Gasoline: visual feedback & you remain with the car
- Electricity is invisible so very hard to judge for general public
Right-to-repair = efficient repairs by anyone
• Make sure vehicles stay clean and safe
• Ensure a level playing field for the repair industry

Global trend – usually aligned to more than emissions; taking in EV as well
• Diagnostics & Service solutions available and accessible
• All in-vehicle Diagnostics accessible
• Some rules cover Remote Diagnostics for Connected Cars
Overall Diagnostic System - Cyber Security

Accessibility to all = security threat

- Vehicles have “wide-open” CAN-bus
- Can add Diagnostics to detect “someone acting strange”

Some hacking approaches could be stopped by diagnostics system

<table>
<thead>
<tr>
<th>Hacking method</th>
<th>Diagnostics feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over send CAN message w/ modified contents</td>
<td>High frequency CAN message diagnostics</td>
</tr>
<tr>
<td>Modified SW/Calibration</td>
<td>Active checksum/CVN comparison to reference</td>
</tr>
<tr>
<td>Unauthorized start of diagnostic session (UDS), flashing session, etc.</td>
<td>Session conditions verification – i.e. only at standstill</td>
</tr>
</tbody>
</table>
Very simplified: Focus on any failure that can result in harm or death

- Some of the effort in making the failures non-existent
- Some of the effort in taking away the effect of the failures
- Left-overs covered by diagnostics

ISO 26262 has focus on E/E systems

- BRACE approach is to focus broader – protect for product liability
- EV/REX specific:
  - High-voltage systems
  - Batteries going unstable
  - E-motor is instant torque actuator in both directions
ECE 100 as an example

- Adds specific & detailed requirements
  - “Defects in the powertrain may not result in a movements of a standstill, un-braked vehicle for more than 0.1 meter”
  - “a failed charger as defined” must limit such a defect to 30 minutes”

High-voltage working conditions legislation

- Many differences between regions
- Can also drive diagnostic system design
How to check the fault is to be blamed on the charger station?

- Unhappy feedback from EV users on broken chargers stations
- Different charging systems – even per vehicle

**Mode 1 & 2:**
Slow charging from home socket
By the onboard charger
No communication

**Mode 3:**
Slow & Fast charging AC
By the onboard charger
With communication

**Mode 4:**
Fast DC charging
By the external charger
When DC or home socket charging

- Onboard charger has no communication
- Car notices when current is flowing - does not know if lack of current is normal
- Charge door and car socket have switches to indicate plug-in
- Run diagnostic based on expected current

Charge door (electric unlock)

Car socket switch
EV / REX Diagnostic struggles - charging

When onboard charger is in control and there is communication

- Charging status indicated by LEDs typically
- Adding DTC is possible
- What about charging at multiple stations?
- Only set DTC when repeating issue = vehicle at fault
- Still a “guess” at best
How specific should the diagnostic system highlight the source?

- Does a mechanic need to know battery cell 146 is broken?
- When the repair is “exchange battery pack”?
- How to handle this repair action for “everyone” considering high-voltage?
- Potential issues with compliance to right-to-repair

- Similar trend in conventional powertrain:
  - DCT transmission: broken actuator or sensor = replace transmission
  - Too much end-of-line fine-tuning for accurate control = cannot be serviced
The EV will be full with safety related diagnostics

- A detected dangerous event & no harm or death = OK
- A vehicle can be destroyed in the process but no problem
- Vehicle fire is OK if everyone made it out in time
- But still:
The EV Diagnostic system is not very different than conventional; however:

- Some relief for OBD if pure EV; extra OBD if REX
- New market players and new systems w/o history mean even discuss the basics
- Extra media and public attention means doing things better than conventional
- High-voltage brings new dangers in all parts of the lifecycle
- Invisibility of “refueling” (charging) requires more of diagnostic system

The EV Diagnostic is not more simple or more complex but lacks re-use
Questions?