Training Syllabus to Instruct Bus Technicians  
on Hybrid Drive Systems Operations, Maintenance and Troubleshooting

Abstract: This *Recommended Practice* provides guidelines for establishing a standardized bus maintenance training program related to the theory of operation, maintenance and troubleshooting of bus hybrid drive transmissions and related equipment.

Keywords: Hybrid Drive System, ESS, DPIM, AC Induction motor, regenerative braking, Allison DOC

Summary: This *Recommended Practice* provides transit bus maintenance training and transit bus maintenance departments with typical information to evaluate, develop or enhance current training programs for the diagnosis, repair and maintenance of transit bus hybrid drive systems. Individual operating agencies should modify these guidelines to specifically teach the coach and transmission manufacturers and modes of operation on their local equipment. The training assumes prerequisite knowledge in several areas of Engine, Engine Diagnostics, Trans / Drive Train, and Electrical Electronics Training Standards through level 300.

Scope and purpose: This *Recommended Practice* reflects the consensus of the APTA Bus Standards Program members in conjunction with transit labor organizations, including ATU and TWU, on the subject material, manuals and textbooks, test equipment, methods and procedures that have provided the best performance record based on the experiences of those present and participating in meetings of the program task forces and working groups. APTA recommends the use of this document by organizations that have a training department or conduct training for the maintenance of transit buses, organizations that contract with others for transit bus maintenance training, and organizations that influence how training for transit bus maintenance is conducted.

**Standards logo**Contents

Participants

The American Public Transportation Association greatly appreciates the contributions of the Bus Maintenance Training Working Group, which provided the primary effort in the drafting of this *Recommended Practice*.

At the time this standard was completed, the working group included the following members:

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# Learning environment

For best application of this *Recommended Practice,* a combination of classroom lectures, mentoring, practical training and practice tests should be included in the training program.

# Computer skills and other Pre-requisites

Basic computer skills are now a standard for transit bus technicians. Basic skills and knowledge in the operation of a computer in a Microsoft Windows environment is essential.

Training in Hybrid systems assumes knowledge in several other areas. Technicians should have already received training and/or demonstrated competence in engine, engine electrical diagnostics, electrical systems theory and schematics, and bus control systems.

# Course learning objectives

The Modules listed below implement the Hybrid Training Standards and Learning objectives (See Appendix A) by providing a foundation of theory and safety, introducing the various common components, and providing hands-on exposure to maintenance practices and diagnostics. The underlying learning objectives, organization of the modules and order of instruction of the various tasks have been developed through a Labor-Management Committee of Subject Matter Experts (SME). When a transit bus mechanic demonstrates proficiency in the learning objectives of these modules they should be capable of demonstrating consistent competence in maintaining hybrid equipment on the particular buses of the local fleet

**Module I: Hybrid System Safety**

The objective of this module is to familiarize the employee with all of the critical safety considerations for working on a hybrid system. Special tooling, PPE, and high voltage considerations are emphasized.

**Module II: Hybrid Drive System Theory and Understanding**

The objective of this module is to introduce how hybrid drive systems generate, store, and supply power to operate transit vehicles.

**Module III: Overview of Operations and Components / Three Phase Power Theory**

The objective of this module is to provide technicians with an overview of the operations of each hybrid system component, including Energy storage systems, Inverter modules, power generation equipment, traction motors, and control area network equipment, and how all of these components work together and communicate with the engine and other bus systems

**Module IV: Hybrid Maintenance**

The objective of this module is to provide hands-on practice in the inspection and maintenance of hybrid system components

**Module V: Hybrid Troubleshooting**

The objective of this module is to provide extensive hands on practice in troubleshooting hybrid systems through using OEM software. Technicians will identify common diagnostic troubleshooting codes and work through various troubleshooting steps, perform tests, make adjustments and verify repairs.

# Exam requirements

The minimum acceptable grade to pass the course and all practical tests is 75 percent. Students must pass written tests with a minimum grade of 80 percent. ASE has not developed tests in this subject area. Delivery of training should include written pre and post tests and practical demonstrations from the students to confirm that the learning objectives have been achieved.

# 

# **Abbreviations and acronyms - General**

**APTA** American Public Transportation Association

**ASE** Automotive Service Excellence

**ATU** Amalgamated Transit Union

**DMM** digital multimeter

**DTC** diagnostic trouble code

**FMVSS** Federal Motor Vehicle Safety Standards

**MSDS** Material Safety Data Sheet

**OEM** Original Equipment Manufacturer

**PPE** Personal Protective Equipment

**PPM** Parts Per Million

**R&R** Remove and Replace

**TWU** Transit Workers Union

# **Abbreviations and acronyms – Hybrid System Specific:**

|  |  |
| --- | --- |
| AED | Allison Electric Drives |
| Allison DOC | Allison Diagnostic Optimized Connection - PC based diagnostic tool for troubleshooting |
| BCIM | Battery Control Interface Module |
| C1 …. C3 | Clutch 1 … Clutch 3 |
| CAN | Controller Area Network - a network for all SAE J1939 communications in a vehicle |
| CIN | Calibration Identification Number |
| DC | Direct Current |
| DPIM | Dual Power Inverter Module - responsible for AC-DC conversion and motor controls in the EP 40/50 System |
| DTC | Diagnostic Trouble Codes |
| ECM | Engine control module |
| EP 40/50 System | Allison Transmission parallel hybrid system |
| EV Drive | Electrically Variable Drive - Drive unit for parallel hybrid system |
| ESS | Energy Storage System - Battery assembly that provides high voltage DC power to the EP 40/50 System |
| EVT | Electronically Variable Transmission |
| HEV | Hybrid Electric Vehicle |
| HVIL | High Voltage Interlock Loop - safety circuit that prevents exposure to high voltage |
| OLS | Oil Level Sensor |
| P1 .. P4 | Planetary 1 … Planetary 4 |
| PBSS | Push Button Shift Selector |
| PSM | Pressure Switch Manifold - Part of Transmission Control System located inside the oil pan |
| PTO or P | Power Takeoff |
| RTD | Resistance Temperature Device |
| SAE | Society of Automotive Engineers |
| SID | System ID - identifies compatible calibrations at the system level. The SID is identified on the TCM, VCM, PIM, and ESS calibration labels and is required when performing a service re-calibration of the system or individual component |
| SOC | State of Charge |
| TCM | Transmission Control Module (the "master" controller interfaces with the EV Drive |
| TID | Transmission ID |
| VBS | Variable Bleed Solenoid |
| VCM | Vehicle Control Module |

**Appendix A**

**Hybrid Bus System Learning Objectives / Training Standards**

|  |  |  |  |
| --- | --- | --- | --- |
| **Order of Instruction** | **Transit Bus Hybrid Systems -- Learning Objectives** | | |
| **Course or Module Name** | | |
|  | | Learning Objective Statements |
|  | **Explanation of Prerequisites:** | | |
|  |  | | Knowledge of content in the Engine, Engine Diagnostics, Trans / Drive Train, and Electrical Electronics Training Standards through level 300 is necessary prior to beginning learning on Hybrid systems |
|  |  | |  |
| 101 | **Hybrid System Safety** | | |
|  |  | | Fulfill local high voltage electrical safety certification requirements if applicable |
|  |  | | Demonstrate how to verify that no voltage is present |
|  |  | | Identify what is a safe level of voltage to work with |
|  |  | | Explain the significance of orange cables |
|  |  | | Demonstrate how to use specialized tools for high voltage testing |
|  |  | | Identify purpose and use of insulated tools, and how to identify unsafe insulated tools |
|  |  | | Identify and demonstrate use of PPE for working on hybrids |
|  |  | | Explain required procedures for fall protection and roof access |
|  |  | | Explain special requirements for using jacking and lifting equipment on hybrid buses |
|  |  | | Explain required procedures for blocking off access to bus or components when work is being performed |
|  |  | | Explain and demonstrate Lock out Tag out procedures |
|  |  | | Explain use of a shepherd's hook / hot stick and requirements for two man jobs |
|  |  | | Explain requirements for entering a battery tub / enclosure |
|  |  | | Explain unique precautions and awareness needed for when working inside an ESS |
|  |  | | Explain local Emergency Preparedness and First Responder procedures |
|  |  | | Explain precautions and procedures for washing Propulsion system |
|  |  | | Demonstrate battery disconnect procedure |
|  |  | | Isolate and verify isolation of energy storage unit |
|  |  | | Review any applicable changes from the manufacturer on hardware used; demonstrate how to find information on updates before service |
|  |  | | Identify a hybrid vehicle from a non hybrid vehicle at your location |
|  |  | |  |
| 101 | **Special tools and diagnostic equipment for Hybrid systems** | | |
|  |  | | Use diagnostic tools such as a laptop, software, and data link interface |
|  |  | | Demonstrate how to update software through internet |
|  |  | | Use a hi-pot tester / megger |
|  |  | | Use an isolation tester |
|  |  | | Use a digital multimeter with adequate capabilities (1000 V, auto ranging, Cat 3 or 4) |
|  |  | | Explain the gathering and transfer of information from local computers to vendors (uploads, downloads, e-mails, etc) |
|  |  | |  |
| 101 | **Hybrid Drive Systems Theory and Understanding** | | |
|  |  | | Explain advantages and history of hybrid technologies |
|  |  | | Explain the effects on emissions (greenhouse gases, particulates) and why the capital investments in hybrid technology are being made |
|  |  | | Explain basic differences between parallel and series hybrid systems |
|  |  | | Explain regenerative braking and dissipation of excess power |
|  |  | | Explain function of hybrid cooling system |
|  |  | | Explain high voltage isolation and how it is implemented |
|  |  | | Explain theory of operation, Explain driver's perspective, engine and throttle relationship |
|  |  | | Explain unique service line procedures if applicable |
|  |  | | Explain special towing procedures if applicable (remove axles or drive shaft) |
|  |  | | Identify the system architecture of components, safety precautions for working with, and demonstrate a general knowledge of how these common systems work on hybrid buses at your location: |
|  |  | | Energy storage system |
|  |  | | Power converter |
|  |  | | Power generation |
|  |  | | Hybrid electric drive |
|  |  | | Data communication networks |
|  |  | | Control systems |
|  |  | | High voltage cables |
|  |  | |  |
| 100 | **ESS (Energy Storage System) -- Overview of operations and components** | | |
|  |  | | Explain what an ESS is, and how its design is different from a standard battery system |
|  |  | | Explain capacity and challenges of energy storage, what is it used for, what applications are best for different types of ESS |
|  |  | | Review safety practices for working with high voltage equipment |
|  |  | | Explain voltage ranges in hybrid systems |
|  |  | | Describe ESS chemistry at your location (e.g. Lithium, Lead Acid, Nickel Metal Hydride, and voltages and capacities) |
|  |  | | Explain how ESS is cooled (forced ambient air or conditioned air from HVAC system) and the function of these components |
|  |  | | Identify the location of all components and safety precautions for working with the ESS |
|  |  | | Explain the function of the Control System (internal to ESS) |
|  |  | | Explain the function of the disconnect features (shunt disconnects) |
|  |  | | Explain the function of the mechanical enclosure |
|  |  | | Explain the function of the isolation system |
|  |  | | Explain the function of the ESS cables |
|  |  | |  |
| 100 | **Power converter / Power electronics -- Overview of operations and components** | | |
|  |  | | Identify system architecture of each component and safety precautions for working with the Power Converter |
|  |  | | Explain communication between components in the power converter |
|  |  | | Explain the function of the inverter and how it operates |
|  |  | | Explain the function of the inverter control system and how it operates |
|  |  | | Explain the function of High Voltage Cables and how they operate in the power converter |
|  |  | | Explain the function of DC to DC converter and how it operates |
|  |  | | Explain the function of the Cooling system and how it operates |
|  |  | |  |
| 100 | **Power generation-- Overview of operations and components** | | |
|  |  | | Identify the location of components and safety precautions for working with the motor/generator |
|  |  | | Explain the function of the motor/generator and how it operates |
|  |  | | Explain the differences between parallel and series operation |
|  |  | | Explain how motors/generators functionally replace the starter motor |
|  |  | |  |
| 100 | **High voltage cables-- Overview of operations and components** | | |
|  |  | | Basic Inspection, maintenance, design and function of the AC and DC high voltage cables |
|  |  | |  |
| 100 | **Hybrid Electric Drive / Traction Motor-- Overview of operations and components** | | |
|  |  | Explain how Hybrid Electric Drive works in a Parallel system | |
|  |  | Explain how Hybrid Electric Drive traction motor works in a Series system | |
|  |  | Identify the location of components and safety procedures for working with the Hybrid Electric Drive / traction motor | |
|  |  | Explain the function of AC induction motors and how they operate | |
|  |  | Explain the function and operation of Wheel motors (if applicable) | |
|  |  | Explain how the system captures energy through regenerative braking | |
|  |  | Explain how the Cooling system operates | |
|  |  | Explain the function of the Cables in the Hybrid Electric Drive | |
|  |  |  | |
| 100 | **Data communication networks-- Overview of operations and components** | | |
|  |  | Explain the development of data communications standards; SAE 1587/1708 vs. SAE J1939 | |
|  |  | Describe how CAN (Controller Area Network) / J1939 works | |
|  |  | Explain CAN architecture (i.e. what components are communicating with what else) | |
|  |  | Explain the function and operation of terminating resistors | |
|  |  | Explain the function and operation of Gateways, explain differences between public and proprietary J1939 networks on a bus and communication between these networks | |
|  |  | Explain the function and operation of the Interface with Engine control module or unit (ECM/ECU) | |
|  |  | Explain the function and operation of shielding on data cables to protect from high voltage cable interference | |
|  |  | Explain the system for communication with vehicle's 12/24 volt system through multiplex/Dinex etc. | |
|  |  |  | |
| 100 | **Control systems-- Overview of operations and components** | | |
|  |  | *Explain full vehicle communications on a hybrid bus across several systems* | |
|  |  | *See inverter control system under power converter section* | |
|  |  | *See standards for PLC and Multiplex operation from electrical standards* | |
|  |  | Explain how vehicle control systems interface with hybrid control systems | |
|  |  |  | |
|  | *Classes will be designed around the manufacturer(s) at a given location, can be taught generically as much as possible:* | | |
| 200 | **Energy Storage System -- Inspection and General Maintenance** | | |
|  |  | Explain local regulations for removing and replacing components inside enclosures or tubs | |
|  |  | Demonstrate how to use a laptop to identify problems in the ESS | |
|  |  | Inspect and maintain ESS | |
|  |  | Inspect and maintain ESS Cooling system | |
|  |  | Inspect and maintain Control System (internal to ESS) | |
|  |  | Inspect and maintain Disconnect features (shunt disconnects) | |
|  |  | Inspect, maintain and repair Mechanical Enclosure | |
|  |  | Inspecting and maintain Isolation System | |
|  |  | Inspect and maintain cables in the ESS | |
|  |  |  | |
| 200 | **Power converter / Power Electronics -- Inspection and General Maintenance** | | |
|  |  | Inspect and maintain inverter | |
|  |  | Inspect and maintain inverter control system | |
|  |  | Inspect and maintain High Voltage Cables | |
|  |  | Inspect and maintain DC to DC converter | |
|  |  | Inspect and maintain Cooling system | |
|  |  | Inspect and maintain communication between components | |
|  |  |  | |
| 200 | **Power generation-- Inspection and General Maintenance** | | |
|  |  | Inspect and maintain generator/motor | |
|  |  | Apply knowledge about differences in series and parallel operation | |
|  |  |  | |
| 200 | **High voltage cables-- Inspection and General Maintenance** | | |
|  |  | Inspect and maintain cables | |
|  |  |  | |
| 200 | **Hybrid Electric Drive / Traction Motor-- Inspection and General Maintenance** | | |
|  |  | Inspect and maintain AC induction motors | |
|  |  | Inspect and maintain wheel motors (if present) | |
|  |  | Inspect and maintain operation of regenerative braking function | |
|  |  | Inspect and maintain cooling system | |
|  |  | Inspect and maintain cables | |
|  |  |  | |
| 200 | **Data communication networks-- Inspection and General Maintenance** | | |
|  |  | Verify communication between components on data network | |
|  |  | Inspect and maintain terminating resistors | |
|  |  | Inspect and maintain Gateways | |
|  |  | Inspect and maintain the interface with engine control module or unit (ECM/ECU) | |
|  |  | Inspect and maintain shielding on high voltage cables, and shielding on data cables | |
|  |  | Inspect and maintain communication with vehicle's 12/24 volt system | |
|  |  |  | |
| 200 | **Control systems-- Inspection and General Maintenance** | | |
|  |  | Inspect and maintain hybrid controls' interface with bus multiplex systems | |
|  |  |  | |
|  |  |  | |
|  | *Classes will be designed around the manufacturer(s) at a given location:* | | |
| 300 | **General Troubleshooting and Diagnostic Procedures** | | |
|  |  | | Follow all safety procedures during troubleshooting process |
|  |  | | Verify problem (write up) |
|  |  | | Demonstrate how to approach repeating conditions on a particular bus or fleet |
|  |  | | Demonstrate how to prioritize information from DTCs for diagnosing underlying condition |
|  |  | | Demonstrate how to find DTCs in manufacturer's documentation |
|  |  | | Troubleshoot and diagnose causes of various DTCs using diagnostic tests, troubleshooting trees, vehicle history and/or other information |
|  |  | | Troubleshoot and solve problems where DTCs are not generated |
|  |  | | Demonstrate understanding of using diagnostic software, difference between DTCs on laptop and on touch pad (if applicable), and performing software updates manually if needed |
|  |  | | Follow OEM procedures for repair and replace of diagnosed defective components |
|  |  | |  |
| 300 | **Energy Storage System - Troubleshooting and repairing** | | |
|  |  | | Comply with local regulations when removing and replacing components inside enclosures or tubs |
|  |  | | Demonstrate how to use a laptop to identify problems in the ESS |
|  |  | | Demonstrate ability to identify and repair specific ESS failures |
|  |  | | Troubleshoot and repair ESS Cooling system |
|  |  | | Troubleshoot and repair Control System (internal to ESS) |
|  |  | | Troubleshoot and repair Disconnect features (shunt disconnects) |
|  |  | | Troubleshoot and repair isolation system |
|  |  | | Troubleshoot and repair ESS cables |
|  |  | |  |
| 300 | **Power converter / Power Electronics -- Troubleshooting and repairing** | | |
|  |  | | Demonstrate ability to identify and repair specific power converter / power electronics failures |
|  |  | | Troubleshoot and replace inverter |
|  |  | | Troubleshoot and repair inverter control system (VCM, TCM, etc...) |
|  |  | | Troubleshoot and repair high voltage cables |
|  |  | | Troubleshoot and repair DC to DC converter |
|  |  | | Troubleshoot and repair cooling system |
|  |  | | Troubleshoot and repair data cables and connectors |
|  |  | |  |
| 300 | **Power generation-- Troubleshooting and repairing** | | |
|  |  | | Troubleshoot and repair motor/generator |
|  |  | |  |
| 300 | **Hybrid Electric Drive / Traction Motor-- Troubleshooting and repairing** | | |
|  |  | | Troubleshoot and repair AC induction motors |
|  |  | | Troubleshoot and repair wheel motors (if present) |
|  |  | | Troubleshoot and repair regenerative braking operation |
|  |  | | Troubleshoot and repair exhaust braking operation (if present) |
|  |  | | Troubleshoot and repair cooling system |
|  |  | | Troubleshoot and repair cables and connectors |
|  |  | |  |
| 300 | **Data communication networks-- Troubleshooting and repairing** | | |
|  |  | | Demonstrate use of CAN architecture in troubleshooting components |
|  |  | | Troubleshoot and repair terminating resistors |
|  |  | | Troubleshoot and repair Gateways |
|  |  | | Troubleshoot and repair the interface with Engine control module or unit (ECM/ECU) |
|  |  | | Troubleshoot and repair Shielding on high voltage cables |
|  |  | | Troubleshoot and repair communication with vehicle's 12/24 volt system |
|  |  | |  |
| 300 | **Control systems-- Troubleshooting and repairing** | | |
|  |  | | Troubleshoot and repair hybrid controls' interface with bus multiplex systems |
|  |  | |  |
| 300 | **High voltage cables-- Troubleshooting and repairing** | | |
|  |  | | Remove and replace high voltage cables |
|  |  | |  |
|  | *Optional, offered based on what work is done at the agency, must be manufacturer specific:* | | |
| 400 | **Rebuilding of Motor/Generator** | | |
|  |  | | Remove, rebuild and reinstall motors/generators |
|  |  | |  |
| 400 | **Rebuilding of Hybrid Electric Drive / Traction Motor** | | |
|  |  | | Remove, rebuild and reinstall Hybrid electric drive / traction motors |
|  |  | |  |
| 400 | **Rebuilding of ESS** | | |
|  |  | | Remove, rebuild and reinstall energy storage systems |

**Module I: Hybrid System Safety**

**Goal:** Participants should understand and be able to explain and demonstrate how to comply with all of the critical safety considerations for working on a hybrid bus.

**Objectives:**

Following the completion of this module, the technician should be able to:

* Demonstrate knowledge of critical safety procedures, including but not limited to:
  + Identifying whether voltage is present,
  + Identify and use insulated tools,
  + Demonstrate Lock Out Tag Out procedures,
  + Follow roof access procedures,
  + Explain and demonstrate unique requirements for working within and energy storage system,
  + Explain and demonstrate local emergency and first responder procedures.

**Related Job tasks / OJT checklist:**  OJT Checklists may be used with the Learning objectives listed under the “101 Hybrid System Safety”. All components of high voltage safety training listed in OSHA.gov 29CFR 1910 Subpart S should be covered

**Course Description**:

Participants will receive classroom instruction and demonstrations on a bus where a qualified instructor will familiarize the employee with critical safety practices for high voltage hybrid vehicles. Participants should leave the course with an understanding of the importance of these safety practices and knowledge of how to comply with them.

**Recommended Class Size: 6:1 or fewer (small group is necessary for productive use of laptop software on the bus as a training tool)**

**Pre-requisites: (previous module and/or demonstrated experience)**

Participants should have basic computer knowledge and understanding of bus engine operations.

**Delivery Method** (e.g. Lecture, Hands on, On-line, Lab): Hands-on and Classroom

**Course Duration:** 4-8 hours; the principles of the course should be continuously emphasized through the subsequent modules

**Target Audience**: All new and existing mechanics

**Classroom Equipment and Supplies**:

Notepads, pens/pencils, flip chart or white board (and markers), chart markers, classroom, laptop, projector, highlighters, note cards, and name cards

**Course Materials, Training Aids, and References**:

Student Workbooks, Manuals, Handouts, Power Point, Pre and Post Test questions; laptops with OEM software, buses for use in diagnostic practice

Certification level training for high voltage may be necessary. This course should comply with requirements in OSHA.gov 29CFR 1910 Subpart S and NFPA 70F-2012

**Instructor:**

**Course Developer**: Brian Lester, EDSI

**Subject Matter Experts**: Contact APTA

**Revision Dates:** 6/18/12

**Follow Up:** Most recent revision should be sent to committee for feedback

**Instructor and Course Evaluation:** Local course evaluation sheets should be used if present.

**Module II: Hybrid Drive Systems Theory and Understanding**

**Goal:** Participants should understand and be able to explain the overall theory of operation of hybrid drive systems, and the general operation and components of the major subsystems. Participants will also learn about special tools for hybrid maintenance.

**Objectives:**

Following the completion of this module, the technician should be able to:

* Demonstrate understanding of hybrid drive system theory, including:
  + Advantages and history of hybrid technologies
  + Advantages on effects on emissions and return on investment
  + Parallel vs. Series system differences
  + Role of regenerative braking
  + Hybrid cooling system
  + High voltage isolation
  + Special driving considerations, unique service lines, and special towing procedures if applicable
* Demonstrate uses of special tools and diagnostic equipment including:
  + Laptop, software and interface
  + Hi-pot testers, isolation testers and digital multimeters
* Identify the system architecture of components, safety precautions for working with, and demonstrate knowledge of how these components work on hybrid buses at your location:
  + ESS
  + Power Converter
  + Hybrid Electric rive
  + Data Communication Networks
  + Control Systems
  + High Voltage Cables

**Related Job tasks / OJT checklist:**  OJT Checklists may be used with the Learning objectives listed under the following modules in the training standard:

|  |
| --- |
| 101 Theory and Understanding of Hybrid Systems |
| 101 Specialized Tools and Test equipment for Hybrid Systems |

**Course Description**:

Participants will receive classroom instruction and demonstrations on a bus where a qualified instructor will teach the general theory of hybrid drive systems, the structure of major sub-components, and common specialized tools used for hybrid maintenance. Participants should leave the course with an understanding of how a hybrid drive system works on a transit vehicle

**Recommended Class Size: 6:1 or fewer (small group is necessary for productive use of laptop software on the bus as a training tool)**

**Pre-requisites: (previous module and/or demonstrated experience)**

Participants should have basic computer knowledge and understanding of bus engine operations.

**Delivery Method** (e.g. Lecture, Hands on, On-line, Lab): Hands-on and Classroom

**Course Duration:** 8 hours

**Target Audience**: All new and existing mechanics

**Classroom Equipment and Supplies**:

Notepads, pens/pencils, flip chart or white board (and markers), chart markers, classroom, laptop, projector, highlighters, note cards, and name cards

**Course Materials, Training Aids, and References**:

Student Workbooks, Manuals, Handouts, Power Point, Pre and Post Test questions; laptops with OEM software, buses for use in diagnostic practice

* Allison.com / Allison DOC or equivalent OEM Resources

**Instructor:**

**Course Developer**: Brian Lester, EDSI

**Subject Matter Experts**: Contact APTA

**Revision Dates:** 6/18/12

**Follow Up:** Most recent revision should be sent to committee for feedback

**Instructor and Course Evaluation:** Local course evaluation sheets should be used if present.

**Module III: Overview of Operations and Components / Three Phase Power**

**Goal:** Participants should develop a deeper understanding of the components and operation of the major subsystems in the hybrid bus and explain how three phase power is employed in the transit vehicle.

**Objectives:**

Following the completion of this module, the technician should be able to:

* Identify and explain operations of HV battery, ultracapacitor, ESS cooling system, internal ESS control system, disconnect features, mechanical enclosure, isolation system and cables.
* Identify and explain operations of inverter, inverter control system, high voltage cables, AC to DC converter, and cooling system
* Identify and explain operations of communication between power conversion components
* Identify and explain operations of generator
* Understand application of Three Phase Power in hybrid equipment:
  + Understanding DC power systems
  + Understanding single phase AC power
  + Understanding of three phase power
  + What is three phase power
  + Common in commercial buildings (check for materials)
  + Bus vehicle specific systems overview
  + Parallel and series circuits/systems
  + Troubleshooting software and equipment – usage and applications
  + How is three phase used in hybrid vehicle?
  + Whys is three phase power used in hybrid vehicle?
* Identify and explain operations of AC induction motors, regenerative braking function, traction motor cooling system and related cables
* Identify and explain operations of CAN architecture and J1939 communication; apply to inspection and maintenance of hybrid buses
* Identify and explain operations of terminating resistors, gateways, interfaces with ECM or ECU and communication with vehicle’s 12/24 volt system
* Identify and explain operations of multiplex systems and PLCs on a hybrid bus
* Identify and explain operations of high voltage cables, and shielding on high voltage cables

**Related Job tasks / OJT checklist:**  OJT Checklists may be used with the Learning objectives listed under the following modules in the training standard:

|  |  |
| --- | --- |
| 100 | Energy Storage System -- Overview of operations and components |
| 100 | Power converter -- Overview of operations and components |
| 100 | Power generation-- Overview of operations and components |
| 100 | Final drive / Traction Motor-- Overview of operations and components |
| 100 | Data communication networks-- Overview of operations and components |
| 100 | Control systems-- Overview of operations and components |
| 100 | High voltage cables-- Overview of operations and components |

**Course Description**:

Participants will receive classroom instruction and demonstrations on a bus where a qualified instructor will familiarize the employee with the operation of hybrid bus subsystem components. This will build the foundation for maintenance and troubleshooting in subsequent modules.

**Recommended Class Size: 6:1 or fewer (small group is necessary for productive use of laptop software on the bus as a training tool)**

**Pre-requisites: (previous module and/or demonstrated experience)**

Participants should have basic computer knowledge and understanding of bus engine operations.

**Delivery Method** (e.g. Lecture, Hands on, On-line, Lab): Hands-on and Classroom

**Course Duration:** 8-12 hours

**Target Audience**: All new and existing mechanics

**Classroom Equipment and Supplies**:

Notepads, pens/pencils, flip chart or white board (and markers), chart markers, classroom, laptop, projector, highlighters, note cards, and name cards

**Course Materials, Training Aids, and References**:

Student Workbooks, Manuals, Handouts, Power Point, Pre and Post Test questions; laptops with OEM software, buses for use in diagnostic practice

* Allison.com / Allison DOC or equivalent OEM Resources

**Instructor:**

**Course Developer**: Brian Lester, EDSI

**Subject Matter Experts**: Contact APTA

**Revision Dates:** 6/18/12

**Follow Up:** Most recent revision should be sent to committee for feedback

**Instructor and Course Evaluation:** Local course evaluation sheets should be used if present.

**Module IV: Hybrid Inspection and Maintenance**

**Goal:** Participants should develop experience inspecting and maintaining sub components of the hybrid system, and practice performing an overall PM on a hybrid vehicle.

**Objectives:**

Following the completion of this module, the technician should be able to:

* Inspect and maintain HV battery, ultracapacitor, ESS cooling system, internal ESS control system, disconnect features, mechanical enclosure, isolation system and cables.
* Inspect and maintain inverter, inverter control system, high voltage cables, AC to DC converter, and cooling system
* Inspect and maintain communication between power conversion components
* Inspect and maintain operations of generator
* Inspect and maintain AC induction motors, regenerative braking function, traction motor cooling system and related cables
* Apply knowledge of CAN architecture and J1939 communication to inspection and maintenance of hybrid buses
* Inspect and maintain terminating resistors, gateways, interfaces with ECM or ECU and communication with vehicle’s 12/24 volt system
* Inspect high voltage cables, and shielding on high voltage cables
* Perform a PM inspection on a Hybrid bus
* Perform special repair procedures covered in service bulletins

**Related Job tasks / OJT checklist:**  OJT Checklists may be used with the Learning objectives listed under the following modules in the training standard:

|  |  |
| --- | --- |
| 200 | Energy Storage System – Inspection and General Maintenance |
| 200 | Power converter -- Inspection and General Maintenance |
| 200 | Power generation-- Inspection and General Maintenance |
| 200 | Final drive / Traction Motor-- Inspection and General Maintenance |
| 200 | Data communication networks-- Inspection and General Maintenance |
| 200 | Control systems-- Inspection and General Maintenance |
| 200 | High voltage cables-- Inspection and General Maintenance |
|  |  |

**Course Description**:

Participants will receive classroom instruction and demonstrations on a bus where a qualified instructor will demonstrate inspection and maintenance procedures for hybrid components. Students will practice maintenance procedures on a vehicle, including a full PM and any special service bulletin considerations.

**Recommended Class Size: 6:1 or fewer (small group is necessary for productive use of laptop software on the bus as a training tool)**

**Pre-requisites: (previous module and/or demonstrated experience)**

Participants should have basic computer knowledge and understanding of bus engine operations.

**Delivery Method** (e.g. Lecture, Hands on, On-line, Lab): Hands-on and Classroom

**Course Duration:** 16 hours

**Target Audience**: All new and existing mechanics

**Classroom Equipment and Supplies**:

Notepads, pens/pencils, flip chart or white board (and markers), chart markers, classroom, laptop, projector, highlighters, note cards, and name cards

**Course Materials, Training Aids, and References**:

Student Workbooks, Manuals, Handouts, Power Point, Pre and Post Test questions; laptops with OEM software, buses for use in diagnostic practice

* Allison.com / Allison DOC or equivalent OEM Resources

**Instructor:**

**Course Developer**: Brian Lester, EDSI

**Subject Matter Experts**: Contact APTA

**Revision Dates:** 6/18/12

**Follow Up:** Most recent revision should be sent to committee for feedback

**Instructor and Course Evaluation:** Local course evaluation sheets should be used if present.

**Module V: Hybrid Troubleshooting**

**Goal:** Participants should be able to hook up diagnostic software, obtain and evaluate information and perform appropriate repairs to the hybrid drive system.

**Objectives:**

Following the completion of this module, the technician should be able to:

* Explain how to find codes, interpret codes and follow repair procedures
* Explain methods to approach duplicate problems and repeat conditions
* Explain special advanced troubleshooting techniques for energy storage systems
* Select proper test equipment to diagnose a given set of symptoms
* Demonstrate proficiency in locating information in service manuals and on intranet
* Hook up and use OEM software, demonstrate proficiency at navigating menus, identifying codes, performing tests, and following troubleshooting trees
* Troubleshoot ESS problems
* Troubleshoot Inverter module problems
* Troubleshoot AC induction motor
* Troubleshoot data communication problems
* Apply knowledge of bus control systems to troubleshooting hybrid drive components

**Related Job tasks / OJT checklist:**  OJT Checklists may be used with the Learning objectives listed under the following modules in the training standard:

|  |  |
| --- | --- |
| 300 | General Troubleshooting and Diagnostic Procedures |
| 300 | Energy Storage System - Troubleshooting and Advanced Diagnostics |
| 300 | Power converter / Power Electronics -- Troubleshooting and Advanced Diagnostics |
| 300 | Power generation-- Troubleshooting and Advanced Diagnostics |
| 300 | Final drive / Traction Motor-- Troubleshooting and Advanced Diagnostics |
| 300 | Data communication networks-- Troubleshooting and Advanced Diagnostics |
| 300 | Control systems-- Troubleshooting and Advanced Diagnostics |
| 300 | High voltage cables-- Troubleshooting and Advanced Diagnostics |

**Course Description**:

Participants will receive hands-on instruction and practice diagnosing hybrid drive systems. The course will be taught so each student practices with a laptop OEM software program and explore and repairs a variety of common and critical diagnostic trouble codes. General troubleshooting best practices will be emphasized throughout the course.

**Recommended Class Size: 6:1 or fewer (small group is necessary for productive use of laptop software on the bus as a training tool)**

**Pre-requisites: (previous module and/or demonstrated experience)**

Participants should have basic computer knowledge and understanding of bus engine operations.

**Delivery Method** (e.g. Lecture, Hands on, On-line, Lab): Hands-on and Classroom

**Course Duration:** 4-8 hours; the principles of the course should be continuously emphasized through the subsequent modules

**Target Audience**: All new and existing mechanics

**Classroom Equipment and Supplies**:

Notepads, pens/pencils, flip chart or white board (and markers), chart markers, classroom, laptop, projector, highlighters, note cards, and name cards

**Course Materials, Training Aids, and References**:

Student Workbooks, Manuals, Handouts, Power Point, Pre and Post Test questions; laptops with OEM software, buses for use in diagnostic practice

Allison DOC software and manuals, sufficient laptops, buses and connections for all students to get significant hands on training time.

**Instructor:**

**Course Developer**: Brian Lester, EDSI

**Subject Matter Experts**: Contact APTA

**Revision Dates:** 6/18/12

**Follow Up:** Most recent revision should be sent to committee for feedback

**Instructor and Course Evaluation:** Local course evaluation sheets should be used if present.