MIH Recommended Powertrain Standard

Ver 1.0

MIH Consortium

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Document information

- Document Version: MIH Recommended Standards V1.0
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1.0 Revision history

Table 1: Revision History

Ver.	Date	Edited by	Company	Changes
0.1	2024/06/15	Ryan Chang	Foxconn New EV Team	First version document release
1.0	2024/06/24	Ryan Chang Ted Lien	Foxconn MIH	Refinement per committee review

2.0 Acronym list

Table 2: Acronym list

ABS	Anti-lock Braking Systems
ADAS	Advanced Driver Assistance Systems
AHF	Active Heating Function (for battery heating)
BCU	Battery Control Unit
BMS	Battery Management System
CAN	Controller Area Network
DCAC	DC-to-AC converter
DCDC	DC-to-DC converter
ECO	Economical Mode for driving fuction
EESM	Electric Excited Synchronous Motor
EMC	ElectroMagnetic Compatibility
EPAS	Electric Power Assisted Steering
ESC	Electronic Stability Control
FuSa	Functional Safety
HVAC	Heating, Ventilation, Air Conditioning
NVH	Noise, Vibration, Harshness
OBC	On board charger
OEM	Original Equipment Manufacturer
O&M	Operation and Maintenance
OTA	Over The Air (Update)
PDU	Power Distribution Unit
PTC	Positive Temperature Coefficient heater
Powertrain	EV Powertrain system combining traction motor, inverter and gear reducer
SDM	Software Defined Motor
SDV	Software Defined Vehicle
VCU	Vehicle Control System
VoC	Voice of Customer

3.0 Abstract (Summary)

This powertrain system standard document was developed and confirmed by MIH and partners. The purpose of this document is to help Powertrain developers understand how to standardize the powertrain system and shorten development time, control quality, reduce costs and produce competitive products.

4.0 Status of this document

- MIH Recommended Standards V1.0

5.0 Introduction

The standardization document is to assist developers in determining the appropriate type of powertrain system, including key components and specification ranges.
To reduce transmission losses of powertrain system, developers often integrate the powertrain system and move it closer to the axle end. Therefore, we define the EV powertrain as E-Axle and vice versa.[1]
Through the content of this document, developers can understand current challenges and how to use standardization methods to enhance overall competitiveness.

5.1 Description of requirement (Why/What for whom)

- End users want good performance vehicles and can keep functions up to date for longer vehicle life. (SDM)
- OEMs need competitive Powertrain with minimum design change from vehicle side.
- Suppliers need standard to reduce development cost and enhance adaptability to different vehicles and markets.
- Mission: MIH makes Powertrain standard to fit the needs of End users, OEMs, and suppliers.
- The Powertrain requirement at each stage is shown in Figure 1.

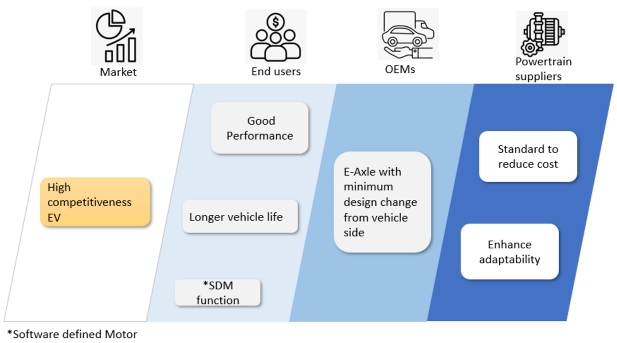

Figure 1: Powertrain requirement description

5.2 Powertrain standard scope

This document outlines the standardization requirements for the Powertrain of electric vehicles. The integrated 3-in-1 Powertrain includes the traction motor, the inverter and the single-speed gear reducer simplifying the Powertrain design making the whole system more compact and efficiently.

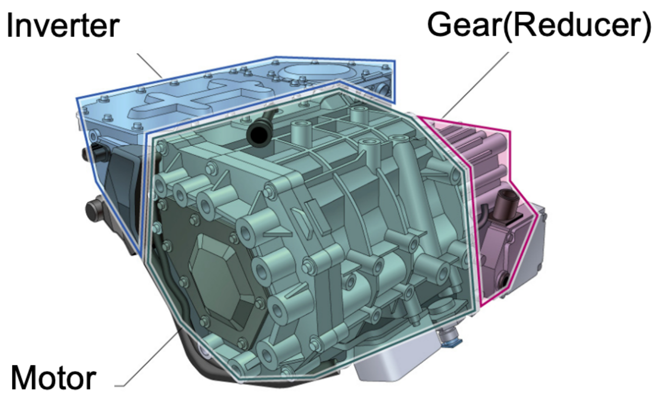

Figure 2: The 3-in-1 powertrain [1][4]

Currently, the essential product in powertrain integration is the 3-in-1 system, which combines the motor, inverter, and reducer. This integration aims to create a more compact design, reducing the number of water hose fittings, connectors, and power cables. Additionally, more and more OEMs are attempting to integrate more components—OBC, DCDC converter, PDU, BMS, VCU, PTC, AHF, DC-AC converter into an X-in-1 system. The motivation of Chinese OEMs is 'cost', and the demotivation of other countries is mainly 'reliability'. Figure 3 shows a 7-in-1 example from Huawei.

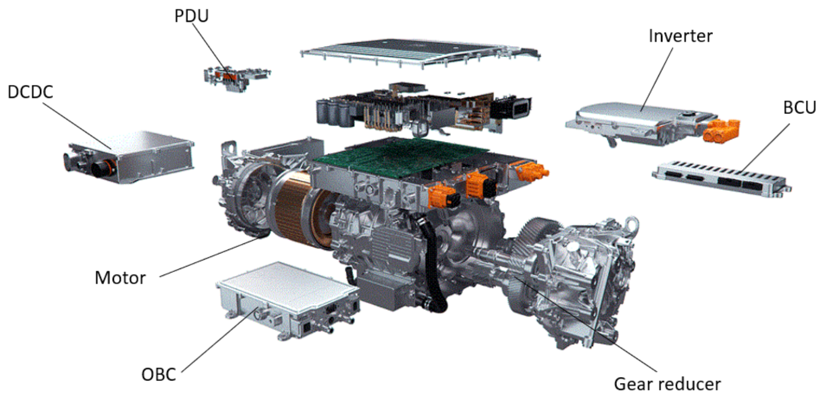

Figure 3: The 7-in-1 powertrain (Huawei)

The pros. and cons. of X-in-1 are as below.

Pros.

1. Cost reduction
   step1: housing, harness, connector reduction (very expensive parts)
   step2: multiple PCBA => single PCBA
   step3: multi MCU => single MCU, commonization of power modules (3=>2 etc.)
2. Simplify layout operation (but X-in-1 itself is big.)

Cons.

1. Reliability
2. Field maintenance
3. Difficulty of software development
4. X-in-1 size is big, so sometimes X-in-1 interferes with the vehicle body.
5. As the parts supplier point of view, large number of variations => difficulty of commonization

By the investigation results, many Chinese OEMs selected their own functions, but these 6 functions are common.
3-in-1 + DCDC, OBC and PDU.
So, these 6-in-1 may be a base module of X-in-1.

In addition to these 6 functions, there may be more functions to be integrated as well.

BMS: Battery Management System
VCU: Vehicle Control System
PTC: Positive Temperature Coefficient heater
AHF: Active Heating Function (for battery heating)
DC-AC converter

For example,

BYD 8-in-1 is 6-in-1 above + VCU + BMS
GAC TOYOTA and AION 7-in-1 is 6-in-1 above + PTC

Basically, VCU and BMS are not easy to develop by the suppliers. These components must be developed with OEMs. We will continue to standardize the charging system in addition to the powertrain standard. This will allow us to expand to 5-in-1, 7-in-1 and X-in-1 systems.

5.3 Benefits of standardization for powertrain

Standardization in Powertrain manufacturing process brings significant benefits across all stages, including design, manufacturing, inspection and O&M. This approach ensures efficiency, cost savings, and improved quality control. Implementing standardization can contribute to cost reductions of approximately 15 to 30% at each stage, illustrated in figure 4.

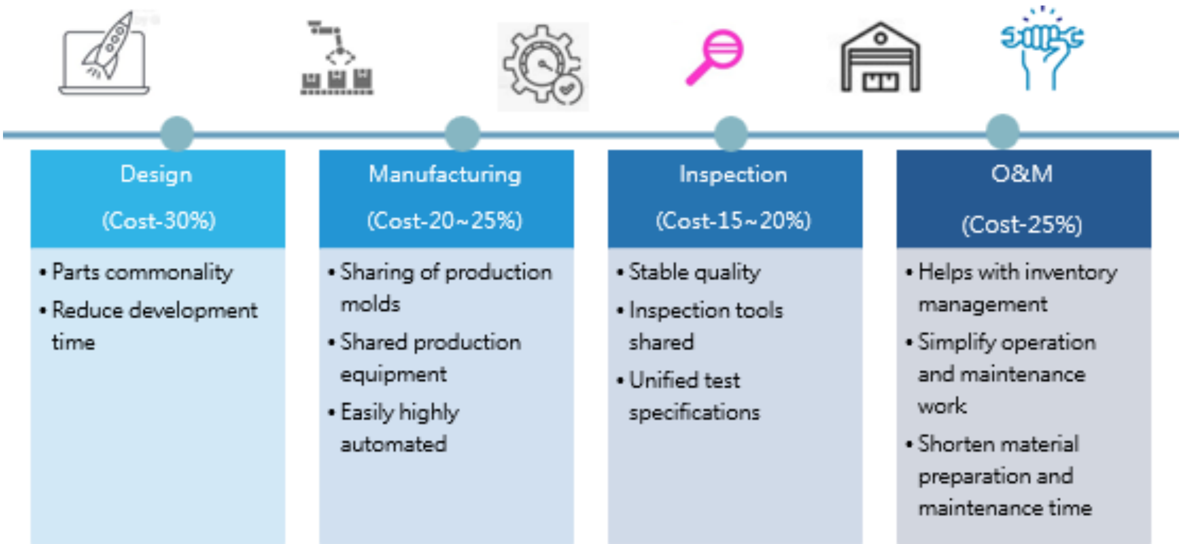

Figure 4: The contribution of standardization for entire process

6.0 Powertrain development trends and challenges

In the early days, the power system was not easy to integrate because the components had different professional fields. However, to meet the requirements of space, efficiency and cost, standardization and integration have been gradually completed, as illustrated in figure 5.

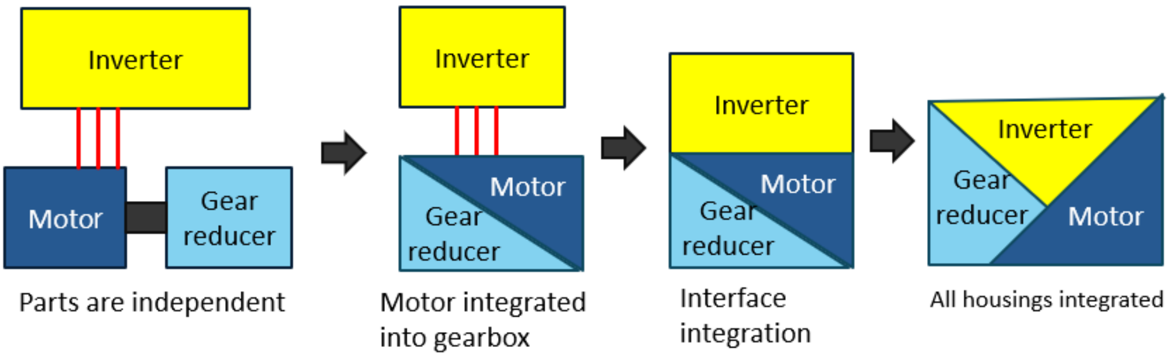

Figure 5: Powertrain integration process [2]

However, there are still challenges in powertrain system integration, such as:

1. The resonate of system resonance on NVH
2. Heat dissipation and bearing life
3. EMC interference
4. The difficulty of cross-department design integration

7.0 Powertrain system architecture

The efficiency of the electric vehicle power system directly affects the driving range. Standardizing and integrating the powertrain system will significantly improve the overall efficiency of the system. Figure 6 shows the typical Powertrain architecture.

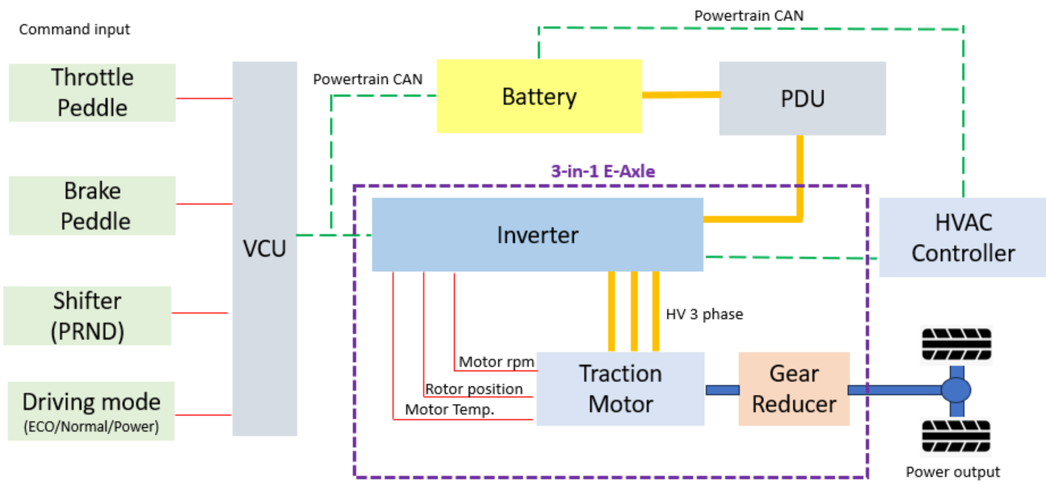

Figure 6: Typical architecture of the 3-in-1 powertrain

8.0 Standardization of key components

8.1 3-in-1 efficiency standard

The 3-in-1 efficiency standard is based on the power module and WLTC driving cycle.

IGBT power module: 90%@CY2025, 91%@CY2027

SiC power module: 92%@CY2025, 94%@CY2027

8.2 Traction motor standard

The standardization in the motor parts is mainly divided into Output power, Wiring, Cooling method, Stator diameter, Magnet and Power density. By increasing the slot fill factor and optimizing the magnet configuration design, the power density of the motor can be improved.[3]

Table 3 lists the items that must be considered for motor standardization and the recommended specification scope.

Table 3: Key items and specifications for motor standardization [1]

Output (kW)	Wiring	Cooling method	Stator diameter	Magnet	Power/Torque density
Peak output (20sec.) 50 (φ150) 75 (φ150) 100 (φ180) 135 (φ180) 150 (φ180) 200 (φ220)	**Hairpin**: 200k/y qty up, or high power 100kW and more **Round wire**: others like 50kW and less, or small volume variations	< 50kW : air 50-100kW: water 100kW- : oil	Outside φ(mm): 150 (-75kW) 180 (75-150kW) 220 (150kW -) *ps. φ220 can cover 250kW if necessary.* *If 800V is needed, φ220 can be commonly used. (more than 200kW)*	**Magnet**: rare-earth **Non-magnet**: EESM *ps. difficult to standardize due to tech not clear*	Power density 2.19 kW/kg by volume: *-power density (kW/litter)* *-torque density (Nm/litter)* by weight: *-power density (kW/kg)* *-torque density (Nm/kg)*

8.3 Inverter standard

The main reason of using SiC power modules in inverter is high efficiency and short charging time (in case of 800V). When choosing the appropriate power module (IGBT or SiC) for a 400V or 800V platform, considerations should include system voltage levels, efficiency requirements, thermal management needs, budget constraints, size and weight factors. In a 400V system, IGBT is usually the more economical choice, while in an 800V system, SiC modules offer better performance and efficiency. However, even in a 400V system, SiC modules have their value, particularly in applications demanding high efficiency and performance. Selecting SiC modules can provide long-term cost savings and performance benefits. Although the initial investment may be higher, the overall cost can be more economical due to energy savings and reduced cooling costs during operation.

Table 4 lists the items that must be considered for inverter standardization and the recommended specification range.

Table 4: Specifications for inverter standardization [1]

Power Module	Film capacitor	Controller
650-700V and peak current ~400A (-75kW) ~600A (75-135kW) ~800A (135kW-)	3 capacities depends on the output, like: 300μF 400μF 500μF	1. Functional Safety 2. Cyber Security 3. Motor control 4. OTA *ps. changeable:* *-calibration parameter* *-diagnosis* *-CAN matrix*

8.4 Gear reducer standard

The standardization of gearbox is mainly based on the vehicle's maximum speed, motor speed and torque, tooth surface grinding accuracy, etc., which will also affect NVH. Generally, the transmission ratio range is determined when the gear center distance is fixed. The gear lubricant circuit also needs to consider the heat dissipation of the motor. The gear reduction ratio standard is 12:1~8:1, as illustrated in figure 7.

Figure 7: 12:1~8:1 ratio gear reduction [1]

9.0 Conclusion

The standardization of EV powertrain is a competitive product specification produced by MIH and partners after analyzing mainstream market demand.

The proposed standardization 3-in-1 Powertrain, the peak efficiency should be more than 90% based on IGBT or 92% based on SiC for 2025, with power density more than 2.19[1]. The key components and specification range should cover:

- Traction motor: Specifications for power output range 80~180kW.
- Inverter: Standards for control algorithms, interfaces, SiC power module (Optional if necessary), functional safety and Cybersecurity.
- Gear reducer: Single-speed ratio 12:1~8:1, specification suitable for various driving conditions.

Standardizing the 3-in-1 Powertrain offers significant benefits across the automotive value chain. By addressing the needs of end users, OEMs, and suppliers, the MIH Alliance can drive the adoption of standardized Powertrains, leading to cost reductions, improved vehicle performance, and greater market efficiency.

10.0 Further research directions

EV needs to have the core competitiveness of high-power density, while meeting the key indicators of high efficiency, small size, light weight, high reliability and must be interoperable with various vehicle models. It is still necessary to continue to pay attention to the following during the development process

- Software defined motor (SDM) development technology can provide a comprehensive view of system status, improve ADAS, driving modes, perform predictive maintenance and extend product life.
- High-voltage architecture above 400V, and standardized integration with high-voltage systems
- The definition of the drive type used for front-wheel drive or rear-wheel drive, and the standardization and modularization of dual-motor drives in the future
- Technical applications of high-speed bearings and shaft seals, especially the problem of bearing electrical corrosion.

11.0 References

〔1〕 MIH and partner Internal materials

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〔4〕 The original figure of 3-in-1 powertrain
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