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Development of Electric Drive System for Small Vehicles

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Abstract

At PUES Corporation we have developed an electric drive system suitable for small vehicles and motorcycles that transports heavy loads. The replacement of the energy sources from fossil fuels reduces the greenhouse gases. The key point in this development is the expandability to be used for a wide range of applications, in order to make effective cost reductions through mass production. The developed electric drive system was evaluated reliability, safety and durability based its on the requirements of a market vehicle. The electric drive system that matches the various vehicles is ready for use.

Keywords: Electric Motorcycle, Scooter, Quadricycle, Micro electric vehicle, Cost, Reliability

1 Introduction

Mainly in developing countries such as those in the ASEAN, the motorcycle is used as the prevailing mode of transportation, but measures for the reduction of the greenhouse gases here are still incomplete, and efforts to find fossil fuels alternatives become important.

On the other hand, an electric drive system is suitable for motorcycles and small vehicles as commuter vehicles/TukTuks from advantages shown below in compared with conventional engine.

- Zero emission gases
- High quietness
- Available for narrow parking space
- Safety running by electric control
- No need to develop fuel supply infrastructure

However, there has been little progress in the popularization of environmentally friendly electric motorcycles/small vehicles for the reasons listed below.

(1) The performance does not satisfy the market requirements
(2) The reliability and safety is insufficient
(3) The cost is not sufficiently reduced

We developed the electric drive system to address these issues for popularization of electric motorcycles/small vehicles. (Figure 1)

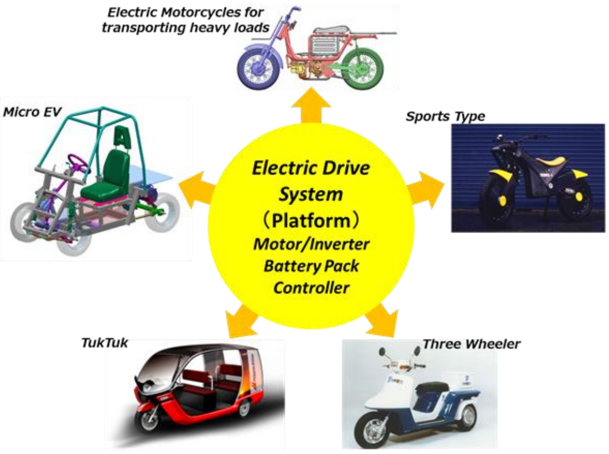

Figure 1: Electric drive system for popularization

2 Development

2.1 Development policy

The vehicle body shape is different between a motorcycle for transporting heavy loads and the small electric vehicle but there are many similarities in the components that make up the electric drive system. Therefore, an electric drive system that can become a compatible platform to fit the various body shapes such as motorcycle or small vehicle was developed.
The most important point in the development was a total system that has been integrated.
The development aimed that vehicle manufacturers who purchases this system can launch electric vehicles without developments of themself. Due to this business model, the vehicle manufacturer can easily reduce development costs and shorten the development time.

2.2 Electric drive system overview

The system is consisted by components as below. (Figure 2)

- Motor/Inverter
- Battery Pack
  - Battery
  - Battery Management System (BMS)
  - Vehicle Control Unit (VCU)
  - DC/DC Converter (DC/DC)
  - Junction Box (J/B)
- Charger

Each component is connected by CAN communication. In addition, it is easily possible to add a control unit used in the vehicle through the CAN. Charging of the auxiliary battery and supplying power to the accessories e.g. lamps, indicators etc. is performed by the DC / DC converter. Each component is waterproof by itself.

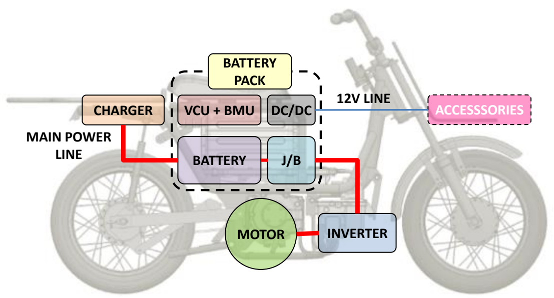

Figure2: System overview

2.3 Components

Vehicle to apply the present system is a small vehicle for delivery and a motorcycle that transports heavy loads. Output power required for these vehicles is 6-15 [kW]. The motor output power increases as the system voltage increases. Therefore the motor/inverter has been designed to be able to output 6 [kW] maximum power at approx. 72 [V]. Vehicle manufacturer can be obtained the performance required for the vehicle according to combination of appropriate system voltage and the motor/inverter. System voltage is assumed to approx. 300 [V], the maximum output is up to approx. 15 [kW]. (Figure 3)

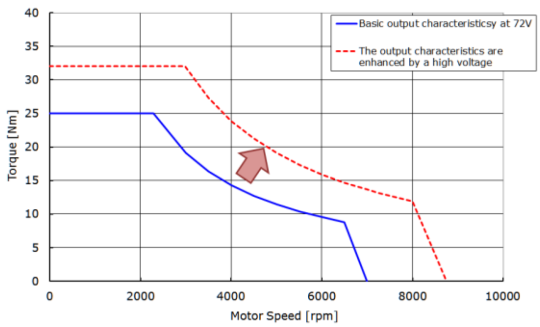

Figure 3: Enhanced output characteristics

2.3.1 Motor/Inverter

A motor/inverter was developed that can cover an output range of 6 to 15 [kW] by changing the system voltage. A small, lightweight permanent magnet synchronous motor was made, and we aimed at reducing costs by giving consideration to part selection and design. Adopted an inexpensive hall effect sensor to the rotor position sensor in order to be compact and low cost. The principle of the sensor is a primitive, but it is possible to drive by vector control method. (Figure 4)
For simple air cooling structure, motor/inverter are suitable for a small vehicle.

Table 1: Motor basic specification

Motor type	IPMSM	
Motor Structure	Inner rotor Distributed winding stator	
Cooling	Air cooling	
Rated Voltage	72 V	300 V
Maximum Output	6 kW	15-20 kW
Maximum Torque	25 Nm	32 Nm
Maximum speed	6000 rpm	9000 rpm
Maximum system efficiency	> 90%	> 90%

Figure 4: Motor

As for the inverter, we consider the diversion of component-layer, design-layer and implementation-layer. Therefore, the quantity of common parts when it is deployed in other applications increases; it is possible to lower cost in parts procurement. Specifically, the output increase due to higher voltage is possible by replacing the components such as capacitors and switching devices an inverter. (Figure 5)

Figure 5: Inverter

The system efficiency map is shown in Figure 6 in the case of the system voltage is 72 [V]. The system efficiency has been achieved 80% or more over a wide operating range.

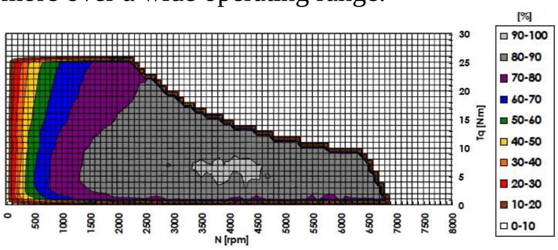

Figure 6: System efficiency

2.3.2 Battery Pack

In order to achieve cost reduction through mass production, we adopted a cell module that is used for mass production electric vehicles. The battery control board, junction box and DC/DC converter are integrated into the battery pack to achieve the smaller and lightweight pack. VCU is integrated with BMS for cost reduction. Due to the rapid development of vehicle batteries it is important to adopt the latest battery to improve performance and achieve cost reduction. The characteristics of the battery are required by the vehicle variety.

Depending on the application, it may be necessary to select the different characteristics of the battery. For example, one application may need a high output small and lightweight battery. The other application may need a long life and low cost battery. Thus, the concept of an electric drive system is the idea of selecting the most suitable type of cell module each time, rather than fixing the battery cell module to one type. Figure 7 shows battery pack for the prototype electric motorcycle we developed.

Figure 7: Battery pack

2.3.3 Charger

We have developed to correspond to both charging methods. Two charging methods are the normal charging for use in household outlets and the quick charging to shorten the charging time.

a) Normal Charger

Charger was developed to accommodate the requirements of various vehicle manufacturers by changing the setting of the charging voltage according to the system voltage. The case is sealed so as to be mounted in the vehicle. The cooling performance is enhanced by potting the heat generating component. (Figure 8)

Table 2: Normal charger specification

Charging method	CC/CV
Input rated voltage(AC)	100 V
Input voltage range(AC)	90 to 100 V
Rated supply frequency	50/60 Hz
Charging voltage	83.0 V (Rated)
Charging current	11.0 A (Rated)
Min. charging voltage	48.0 V
Communication	CAN

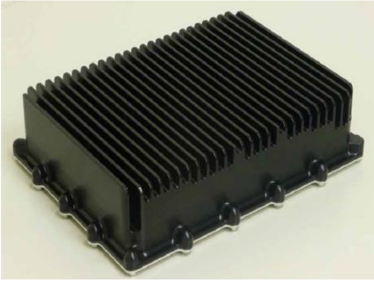

Figure 8: Normal charger

b) Quick Charger

A vehicle is built an interface for quick charging system. In this development, the vehicles are corresponding to CHAdeMO. (Figure 9)

Figure 9: Quick charger

2.4 Reliability test of components

To confirm the reliability, the developed components were subjected to the following tests. Heat cycle test, shelf life test at high-temperature and humidity, vibration test and electromagnetic compatibility (EMC) test. We performed cycle charge-discharge life test at the battery. The motor/inverter were subjected to an endurance test of 500 hours in total. This corresponds to a mileage of 20000 km.

3 Applied to the vehicle

Next, we have developed the prototype electric motorcycle in order to evaluate the electric drive system. The target performance of this prototype electric motorcycle was set to be the same as a motorcycle that is commonly used for newspaper delivery in Japan. In addition, we have assumed that the vehicle manufacturer is likely to be mass-produced. Parts in common with the engine vehicle was diverted parts of mass production engine vehicle. This will be able to achieve cost down. (Figure 10)

3.1 Results of performance test

The mileage per charge was 58.5 [km]. The measurement running mode was 40 [km/h] a constant speed, and the decrement of State of charge (SOC) of the battery was 80 [%]. This SOC values was set by simulates deterioration of the battery capacity. Starting acceleration performance was superior to a target engine motorcycle. Even when loaded with luggage 60 [kg], the maximum speed reached 60 [km/h]. On the same loaded, the maximum climbing angle was 12 [deg].
Vehicle specifications appear in the table below.

Table 3: Vehicle specification

Vehicle weight		122 Kg
Riding capacity		1
Main Battery	Type	Li-ion
	Rated voltage	76 V
	Rated capacity	33.1 Ah
Mileage per charge 40km/h const. SOC90-10[%]		58.5 km
Specific power consumption		36 Wh/km

Figure 10: Prototype electric motorcycle

4 Conclusion

In this project, we have developed the versatile electric drive system for the Micro Electric Vehicle. The electric drive system was tested of reliability, and was applied to the prototype motorcycle.
We plan to improve reliability, further the cost reduction and more. We have the effort to sell the electric drive system which was developed for the vehicle manufacturers.
As a result, by the popularization of electric small vehicles, greenhouse gases reduction is expected.
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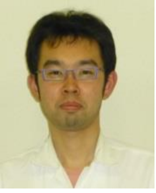

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