CANopen in light electric vehicles

Holger Zeltwanger

– CAN in Automation international users and manufacturers group –

Light electric vehicles (LEV) driven by battery-powered motors require embedded communication networks. In order to standardize the communication between the different devices, some suppliers and some vehicle manufacturers have selected the CANopen application layer. The paper discusses the technical and market requirements and the possible CANopen profile solutions.

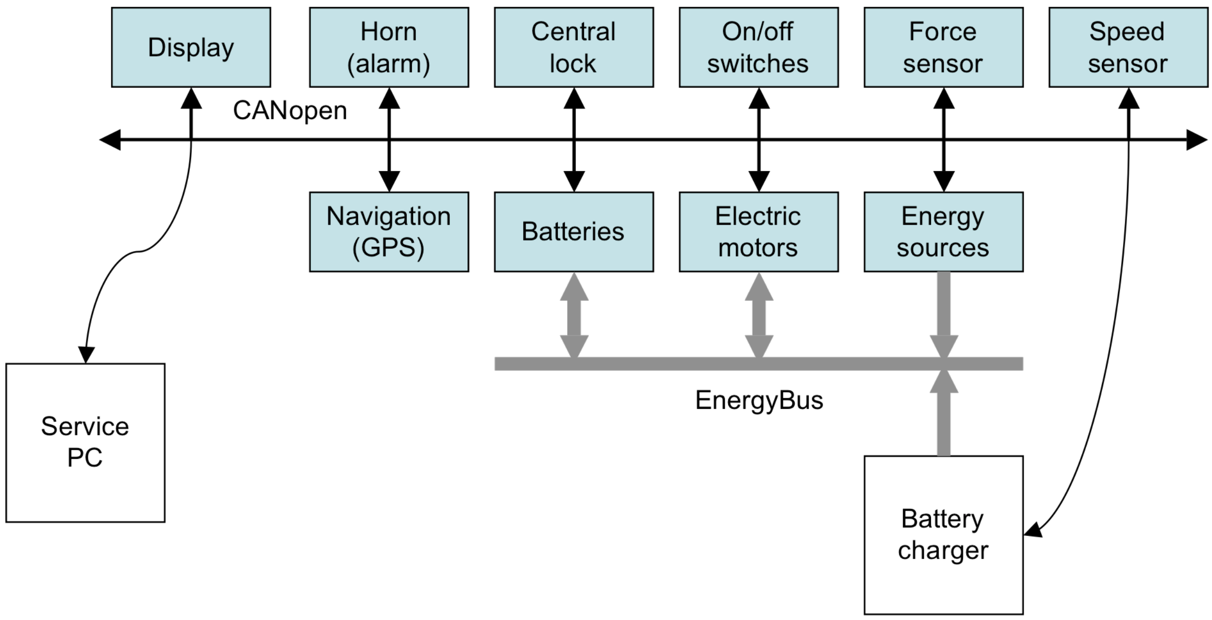

Fig.1: Possible system architecture in an LEV (e.g. Pedelec)

Introduction

Light electric vehicles (LEV) include Pedelecs (bikes with electric motors), motor scooters, and many other battery-powered small vehicles. The largest market is of course the bicycle with electric motor. Last year there have been sold about 18 millions of Pedelecs, the majority in China, of course. The North American and the European markets are very small compared with the Asian markets. Just a few hundred thousands are sold in USA and Europe.

In many Asian countries, the highest prior requirement is the low price for the LEV. According to the EnergyBus organization, the cost of a bike is the same as for the service (repair and maintenance). However, labor cost is in Asia very low. In USA and Europe, the quality of Pedelecs must be much higher due to the high labor cost in the garages. The Japanese market requests a maintenance-free lifetime of 5 to 7 years.

The Pedelec fleets of some European post mail services require more sophisticated products with standardized electrical interfaces, in order to keep the service cost as low as possible. In particular, the number of spare parts should be reduced as much as possible.

On behalf of the EnergyBus organization, the c&s service provider has evaluated several communication technologies for the use in LEVs. Prof.

Lawrenz and his team considered CAN. LIN, USB, I^2C, and RS-485.

Technical requirements

The most sophisticated Pedelecs will require about 16 devices to be connected via a standardized network. Fig.1 shows an example of an LEV with embedded network. The initiator of the research study demanded Pedelecs with GPS and navigation devices for the high-end tourism markets as well as dedicated medical devices for heart rate controlled assistance systems.

The estimated bandwidth of user data is about 2 kbit/s. This would result in 10 to 15 kbit/s considering protocol overhead on the data link and the application layer for diagnostic (e.g. emergency) and network management (e.g. heartbeat).

Another requirement is the sleep mode functionality, in order to avoid problems with the battery after longer periods of not using and loading the LEV.

It was also required to provide a high level of standardized diagnostic information including vendor, product, and other general information (e.g. operating hours).

Regarding the bus topology, a bus line structure fits best. Star and other topologies are not that well suited.

Very important is also the availability of controller chips for reasonable prices suitable for out-door applications. This includes the temperature range, vibration, and other environmental features.

CAN was the data link and physical layer that fulfilled all technical requirements (Fig.2).

Requirement	CAN	LIN	USB	I^2C	485
Diff. bus	✓	-	✓		✓
> 16 ECUs	✓	-	✓	✓	✓
Bus line	✓	✓	-	✓	✓
Sleep mode	✓	✓	-	-	-
HLP	✓	✓	✓	-	-
Modularity	✓		✓	✓	✓

Fig.2: Research study results

The EnergyBus organization selected CANopen as the standardized application layer for embedded control applications. The CANopen application layer and communication profile as specified in CiA 301 and 302 series provide all necessary communication functions. In order to achieve an off-the-shelf plug-and-play functionality, the development of a dedicated application profile for LEVs is necessary.

CANopen application profile

The first proposals for the standardized CANopen networks in LEVs are designed to provide a battery management system. Up to four batteries may be installed in the network. Besides the stationary battery charger devices, there may be other energy sources, e.g. local photovoltaic, fuel cells, and the decelerating electrical motors.

The high-energy batteries require a specific charging strategy, in order to avoid damages including explosions. So the communication between charging devices and batteries is mission critical. Therefore, the battery provides information on its current state including temperature, time of last charge, etc.

The purpose of the CANopen interface of the battery module is to provide information to the charger device. The minimum information required is the battery type, battery capacity, number of cells, maximum charge current, maximum charge voltage, maximum discharge current, minimum cut-off voltage, and temperature limits.

Due to the fact that the network shall be available under all conditions, all CANopen power devices shall provide NMT master capability. This means Flying NMT master functionality is required. The non-power devices such as sensors, human machine interfaces, anti-theft devices etc. should be self-starting devices according to the CANopen specification.

All devices shall support heartbeat. Devices with inputs shall produce the heartbeat, and devices with outputs shall consume the related heartbeats.

The CAN physical layer is compliant to ISO 11898-5 (high-speed with low-power mode). The default bit-rate is 125 kbit/s. A termination resistor of 124 Ohm should be provided by default in the battery device.

The application profile specifies the finite state automaton (FSA) for the battery management system. A first proposal is shown in Fig.3.

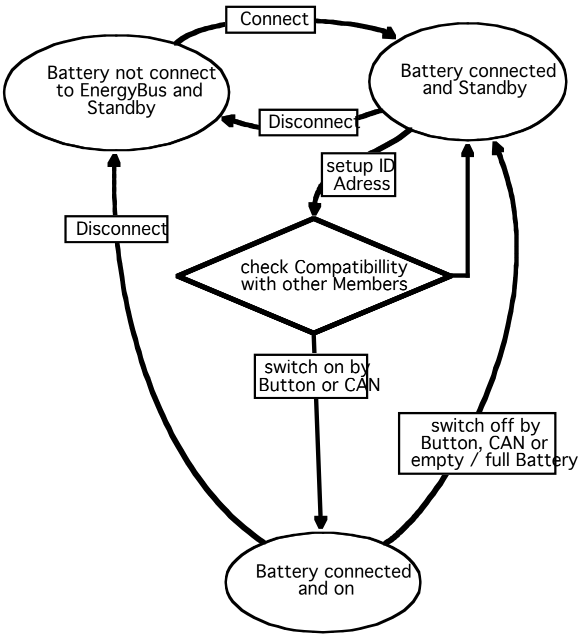

Fig.3 Text

It is required that on an LEV to add and remove multiple batteries and battery chargers in a running system. All other devices should detect the connection and disconnection. For this purpose the boot-up message and the heartbeat is used. Both CANopen services use the very same CAN-ID. Of course, if a power device (e.g. battery or charger) is disconnected from the CANopen network, the power line must be switch off before. If a new power device is connected to the CANopen network, the device will be assigned with a node-ID by means of LSS services. Then the device boots up, configures itself depending on the functions and limits of the other power devices. After successful self-configuration of the power devices, the power lines are switched on.

The power management system is not specified in all details yet. There are still some open issues. Regarding the communication it is quite clear that the FSA of the power management system will be controlled by means of PDOs.

The battery devices will provide a number of parameters in its object dictionary indicating the quality of the battery. This includes lifetime, charging time, and several counters (e.g. for short cuts and deep discharges).

To protect the EnergyBus each power device may limit the voltage and current dynamically. For each power device individual switch-off limits may be used. Example: The battery charger may use a 0 to 30% limitation while the photovoltaic device uses a 0 to 70% limitation.

If the batteries could not provide sufficient energy, the non-critical devices (e.g. GPS and navigation) will be not more powered. The switching off will be communicated by means of CANopen services (PDO).

Outlook

The joint task force of CiA and EnergyBus has already started with the development of the CANopen application profile for LEVs. It is intended to finish the specification in the first version by end of this year. In this version, mainly the battery management system will be specified including the electric drives. In the next step other devices such as anti-theft, GPS, navigation, and dedicated medical devices will be added.