CHEMICAL ENGINEERING TRANSACTIONS
VOL. 59, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Zhuo Yang, Junjie Ba, Jing Pan

ISBN 978-88-95608- 49-5; **ISSN** 2283-9216
DOI: 10.3303/CET1759044

Research on the Test of Fuel Cell Electric Rail Based on CANopen

Hui Li, Junli Ren

CRRC Tangshan Co., Ltd, Tangshan 063035, China
lihuitg@hotmail.com

Fuel cell trams have many advantages, such as high efficiency, no pollution, low noise and simple structure. It is recognized as the mainstream of the future electric bus. In order to solve the communication between the components of the fuel cell tram, the topology of the vehicle communication network is designed based on the CANopen bus, and its hardware requirements are put forward. The communication speed and communication mechanism of CANopen bus are established, and the CANopen message structure and protocol are introduced. Finally, the communication nodes were developed based on LPC2194 microcontrollers and TJA1050 high speed CANopen bus drivers. The practical application shows that the system is stable and reliable.

1. Introduction

Fuel cell tram is a new energy vehicle in recent years (Larsson, et al., 2015). The power source uses a fuel cell instead of the traditional internal combustion engine, which can effectively reduce energy consumption (Motapon, et al., 2014; Mejri et al., 2016; Sommer et al., 2016; Murgi et al., 2016; Mahoomd et al., 2017; Le and Tsai, 2017; Bavasso et al., 2017; Wiranarongkorn et al., 2017; Rossi et al., 2016; Saebea et al., 2016; Liemberger et al., 2016; Özkan et al., 2016; Chatrattanawet et al., 2016; Ziogou et al., 2016). The emissions of such vehicles are water, which is a pollution-free vehicle. It has a wide application prospect in the future. The use of computer control of rail vehicles has become the inevitable development of rail vehicle control technology (Aouzellag, et al., 2015). The use of microcomputer control for railway vehicles has become an inevitable trend in the development of railway vehicle control technology. CAN is a kind of bus protocol which is widely used in the world. It has the characteristics of low cost, high speed, good real-time and high reliability (Ansarey, et al., 2014). At present, many domestic and foreign related industries are supporting the development of the CAN protocol. CANopen is an application layer protocol of CAN protocol, which has been widely used in recent years. It has been written into the electrical industry standard (IEC) as the communication standard of automobile transportation industry. There are a lot of application cases in automobile and transportation industry both at home and abroad (Zhang, et al., 2016). In order to solve the information exchange between the controllers of the fuel cell tram, an intelligent communication network is needed. CANopen is the best choice for its outstanding real-time, reliability and flexibility.
Energy plays an important role in the course of human development, and it is also one of the most important material bases to promote the development of human society. Especially in the contemporary era, human beings have entered a period of high energy consumption, and energy has become an important indicator of a country's comprehensive national strength, civilization and people's living standards. The development history of human society shows that every innovation of energy technology brings great and far-reaching influence on the development of productive forces and social change (Washing, et al., 2015).
For the contemporary society, environmental protection has become the core of the sustainable development strategy of human society, and is the key factor affecting the decision-making of energy and science and technology in the world. With the end of the Copenhagen conference in 2009, the concept of low-carbon life has been widely accepted, and environmental protection and energy saving issues have attracted widespread attention (Kim, et al., 2015). With the increase of the requirements for efficient, clean, economic and secure energy system, the fossil energy based energy system is facing great challenges. The production,

Please cite this article as: Hui Li, Junli Ren, 2017, Research on the test of fuel cell electric rail based on canopen, Chemical Engineering Transactions, 59, 259-264 DOI:10.3303/CET1759044

consumption and global climate change of energy are closely related to the greenhouse effect on the earth. Carbon dioxide emissions from carbon - bearing fossil fires are the main cause of the greenhouse effect, which is widespread in the current energy system. The main theme in twenty-first century is to change the current energy system, increase energy efficiency and develop alternative energy sources (Dursun, et al., 2015).

2. Research object

The fuel cell trolley uses a fuel cell or a fuel cell to mix other auxiliary energy devices as energy sources. The drive type is "fuel cell - motor controller - motor - transmission - main reducer - differential - wheel". It uses motor as a power source to replace the traditional car's engine-driven vehicle (Sulaiman, et al., 2015).

Fuel cell trams have many advantages, such as high efficiency, no pollution, low noise and simple structure. It is recognized as the mainstream of the future electric bus. The drive system is different from the traditional car, which uses a large number of power electronic components. The vehicle's electronic control system is quite complex. The traditional wiring method increases the complexity of the circuit and the difficulty of maintenance, so that the reliability of the vehicle control network is reduced. It is difficult to adapt to the development and use of automotive technology requirements. Therefore, the creation of intelligent control nodes and the formation of a new type of fuel cell city bus communication network are very necessary. Compared with the general communication bus, CAN bus has outstanding reliability, real-time and flexibility and so on. So far, CAN bus is the most widely used field bus (Torreglosa, et al., 2014). Therefore, it is very meaningful to use CAN bus to carry on the research of fuel cell city bus communication network.

As CAN bus application layer protocol, CANopen protocol with its unique design has been widely recognized and applied (El Fadil, et al., 2014). Especially in Europe, the CANopen protocol is considered to be a leading standard in CAN-based industrial systems and has been used in medical devices, motion control and measurement equipment industries. However, the fuel cell tram control system has not yet applied the CANopen protocol. The main reason is that the real-time and reliability of CANopen protocol still need to be improved. In addition, the automotive industry also lacks standard application specifications (Xu, et al., 2013).

Fuel cell trams are used as an application platform, and the communication standard is CAN2.0B and J1939 protocol. According to the actual operating conditions and control requirements, we designed a complete communication network. Based on the study of the power system of the fuel cell city bus, the function of each control unit is analyzed, and the network topology of CANopen node is constructed. According to the J1939 protocol, the source address and the message of the network node of the FCCB communication system are defined in detail, and the CANopen node communication test is carried out.

The technical difficulty of fuel cell vehicles is high. It is a large and complex energy system. Its hydrogen production technology is the source, and hydrogen storage technology is the key, and the efficient utilization of hydrogen is the core. With the rapid development and industrialization of fuel cell technology and electric vehicle technology, safe and efficient hydrogen storage technology has become the key to the promotion and application of hydrogen energy. Hydrogen fuel cells mainly consist of two parts: battery and fuel. Its upstream is mainly hydrogen supply and battery parts. The middle reaches are assembled above. It is a complete fuel cell system that can be put into use. Each system is constructed according to its different application areas. The lower reaches include three major areas of fixed, transportation and portable. The core of the fuel cell industry chain lies in the middle reaches of the fuel cell system. The problem of environmental pollution and energy shortage has become increasingly prominent, and new energy vehicles have become a hot research topic all over the world. Fuel cell systems are widely believed to have broad prospects for their high efficiency and near zero emissions.

3. CANopen communication protocol

The model of the CANopen device is shown in Figure 1. The model describes functions that are completely different. Different devices are connected by CAN bus. The CANopen communication protocol interface is used to provide services that send and receive communication objects on the bus. The communication between different CANopen devices is accomplished by exchanging communication objects. The communication sub layer, the object dictionary and the application sublayer and the relationship between them provide the basic operating mechanism for the device. The implementation of the application layer includes the definition of application design and device sub-protocol. The communication sublayer defines four types of objects for CANopen network communication, including process data objects (PDOs), Service Data Objects (SDOs), Network Management Objects (NMTs), and special function objects. It provides all the mechanisms required for data transmission. The object dictionary is the core of the device model. The application sublayer communicates with other nodes by accessing the object dictionary. The communication sublayer writes the data in the object to the corresponding position in the object dictionary.

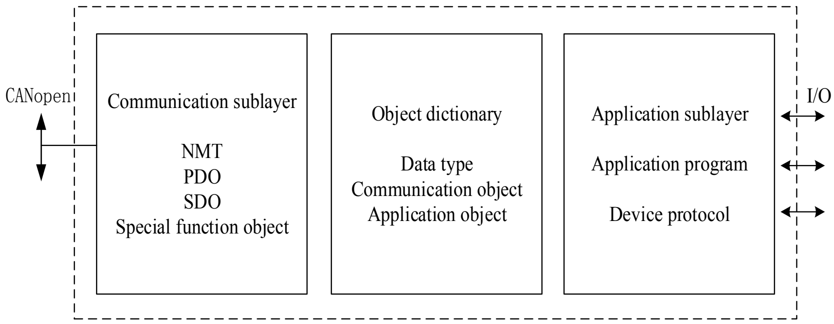

Figure 1: CANopen device model

4. Design of vehicle communication network

The drive system is different from the traditional car, which uses a large number of power electronic components. The vehicle's electronic control system is quite complex. The traditional wiring method increases the complexity of the circuit and the difficulty of maintenance, so that the reliability of the vehicle control network is reduced. It is difficult to adapt to the development and use of automotive technology requirements. Therefore, the design of a powerful CANope bus can effectively solve the problem of information exchange between the controller of fuel cell city bus.
The whole vehicle control system is the core of the whole vehicle control system, which directly affects the reliability, fuel economy and other performance of the vehicle. Vehicle control system is one of the key links in the development process of fuel cell tram. Its main functions include: data acquisition; working state parameters of the acceleration signal and the brake signal, the vehicle speed signal and each component (such as super capacitor voltage and current) were analyzed and calculated, converted into control commands, power source energy distribution; fault diagnosis and treatment and so on. At present, the nonlinear control technology of intelligent control system, such as variable structure control, fuzzy control, neural network, adaptive control, expert system and genetic algorithm, can be applied to the control system of fuel cell tram.

4.1 Design of communication network structure

According to the different needs of vehicle communication, the vehicle communication network is decomposed into CANopen bus-based vehicle control network and LIN-based body control network. As shown in Figure 2, it makes full use of high-speed CANopen bus and low-speed LIN.

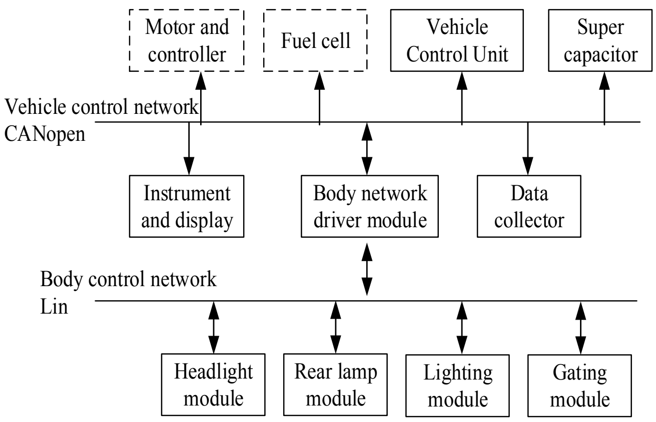

Figure 2: Vehicle communication network structure

In the vehicle control network, the motor and controller, the fuel cell, the vehicle controller, the super capacitor, and the body driver module are bidirectional hair node, while the instrument and the display and the data collector only receive the signal. LIN network controls low-speed front and rear lights, interior lighting, doors and windows and wipers and so on.

4.2 The hardware requirements for network communication

CANopen bus and LIN bus communication cable are used flame retardant 0.5mm shielded twisted pair. Data exchange between two subnets is implemented through the gateway. In order to improve the EMC capability of the network, all CANopen nodes have a 120Ψ termination resistor. Communication cable should be far away from the power line 0.5m above, and the cable shield layer in the car continuous conduction.

5. Vehicle power control network CANopen communication protocol

5.1 Bus communication rate and communication mechanism

In the fuel cell tram system, CANopen bus and LIN bus structure is used to achieve vehicle control, energy management and body control. Each node in the CANopen system requires high real-time communication, and the rate is 250Kbps. Lights, doors and other requirements on the speed is not high. The transmission quantity is large. The rate is 19.2Kbps LIN structure. High and low speed networks need to exchange information through the bridge.
According to the experiment measured CAN bus at 250K rate of communication, each frame of the message occupancy time is 500 μs. Taking into account the reliability of communication, stability and control of real-time, network communication cycle set at 50ms. The communication mechanism adopts the response type. The concrete steps are as follows: After the vehicle controller is initialized, two frames of data are sent every 50ms by broadcast. After receiving the second frame data from the vehicle controller, the components send the data to the vehicle controller in a point-to-point manner according to the priority of the ID and delay the corresponding time. In a cycle, it is only sent once (within 50ms after receipt of vehicle controller data).

5.2 CANopen message structure and protocol table

Table 1 is an allocation table for 29 identifiers. Among them, the priority is 3 bits, and it has 8 priority. R is generally fixed to 0. DP is now fixed to 0. 8 bit PF (PDUFORMAT) is the message code. 8 bit PS (PDUSPECIFIC) is the destination address or group extension. 8 bit SA (SOURCEADDRESS) is the source address to send this message. The SRR bit is the "alternate remote request bit" for a recessive bit. The IDE bit is the "identifier extension" and is a recessive bit in the extended format message frame.

Table 1: CANopen bus network packet structure

11-bit identifier				SRR	IDE	Extended identifier		
Priority	R	DP	PF	SRR	IDE	PF	PS	SA

6. Realization of CANopen communication network system

CANopen communication network node processor is based on 32-bit ARM7TDMI-S LPC2194 microcontroller. ARM instruction processing uses pipelined technology to process and store all parts of the system continuously. The LPC2194 comes with four CANopen interfaces and an internal CANopen controller. As shown in Figure 3, the CANopen bus driver uses a high-speed TJA1050 to implement a link to the CANopen bus. Microcontrollers and bus drivers are optoelectrically isolated to reduce bus-to-microcontroller interference. In the software development of the communication system, the fuel cell tram is used as the core of the vehicle controller to control the work of the relevant parts, and realized the functions of data acquisition, display and alarm. The software design of the communication node adopts the modular design idea, which includes the monitoring program and the initialization module, the message transceiver module, the interrupt service program module and the software expansion interface module.

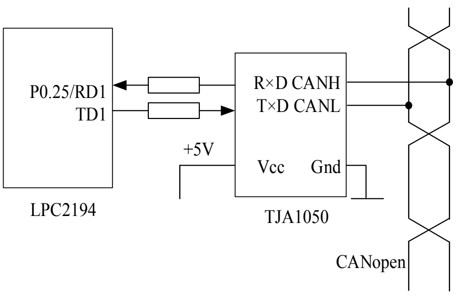

Figure 3: CANopen node hardware connection diagram

7. Conclusions

Based on the CANopen bus technology, this paper designs the vehicle communication network of the fuel cell tram, realizes the communication link between the various parts of the automobile, and reduces the use of the signal line and reduces the complexity of the control network. The results show that CANopen bus has strong stability and reliability, and can realize the control of vehicle communication network conveniently. This system is the preliminary application of CANopen bus in the control network of fuel cell tram. It has a certain engineering application prospects.

Reference

Ansarey, M., Panahi, M. S., Ziarati, H., Mahjoob, M., 2014, Optimal energy management in a dual-storage fuel-cell hybrid vehicle using multi-dimensional dynamic programming. Journal of Power Sources, 250, 359-371.

Aouzellag, H., Ghedamsi, K., Aouzellag, D., 2015, Energy management and fault tolerant control strategies for fuel cell/ultra-capacitor hybrid electric vehicles to enhance autonomy, efficiency and life time of the fuel cell system. international journal of hydrogen energy, 40(22), 7204-7213.

Bavasso I., Montanaro D., Petrucci E., Di Palma L., 2017, Shortcut biological nitrogen removal (sbnr) in microbial fuel cells (mfcs)., Chemical Engineering Transactions, 57, 727-732, DOI: 10.3303/CET1757122

Chatrattanawet N., Hakhen T., Saebea D., Arpornwichanop A., 2016, Performance analysis and control structure design for proton exchange membrane fuel cell, Chemical Engineering Transactions, 52, 997-1002, DOI: 10.3303/CET1652167

Dursun, B., Yaren, F., Unveroglu, B., Yazici, S., Dundar, F., 2015, Expanded graphite–epoxy–flexible silica composite bipolar plates for pem fuel cells. Fuel Cells, 14(6), 862-867.

El Fadil, H., Giri, F., Guerrero, J.M., Tahri, A., 2014, Modeling and nonlinear control of a fuel cell/supercapacitor hybrid energy storage system for electric vehicles. IEEE Transactions on Vehicular Technology, 63(7), 3011-3018.

Kim, Y., Salvi, A., Stefanopoulou, A. G., Ersal, T., 2015, Reducing soot emissions in a diesel series hybrid electric vehicle using a power rate constraint map. Vehicular Technology IEEE Transactions on, 64(1), 2-12.

Larsson, M., Mohseni, F., Wallmark, C., Grönkvist, S., Alvfors, P., 2015, Energy system analysis of the implications of hydrogen fuel cell vehicles in the Swedish road transport system. International journal of hydrogen energy, 40(35), 11722-11729.

Le M.V., Tsai D.S., 2017, Proton conducting fuel cells using the indium-doped cerium diphosphate electrolyte, Chemical Engineering Transactions, 56, 361-366, DOI:10.3303/CET1756061

Liemberger W., Gross M., Miltner M., Prazak-Reisinger H., Harasek M., 2016, Extraction of green hydrogen at fuel cell quality from mixtures with natural gas, Chemical Engineering Transactions, 52, 427-432, DOI: 10.3303/CET1652072

Mahmood N.A.N., Ghazali N.F., Ibrahim K.A., Ali M.A., 2017, Anodic ph evaluation on performance of power generation from palm oil empty fruit bunch (efb) in dual chambered microbial fuel cell (mfc), Chemical Engineering Transactions, 56, 1795-1800, DOI: 10.3303/CET1756300

Mejri I., Mahmoudi A., Abbassi M.A., Ahmed O., 2016, LBM simulation of heat transfer in solid oxide fuel cell, International Journal of Heat and Technology, 34(3), 351-356, DOI: 10.18280/ijht.340301

Motapon, S. N., Dessaint, L.A., Al-Haddad, K., 2014, A comparative study of energy management schemes for a fuel-cell hybrid emergency power system of more-electric aircraft. IEEE transactions on industrial electronics, 61(3), 1320-1334.

Murgi N., De Lorenzo G., Corigliano O., Mirandola F.A., Fragiacomo P., 2016, Influence of anodic gas mixture composition on solid oxide fuel cell performance: Part 1, International Journal of Heat and Technology, 34(S2), S303-S308, DOI: 10.18280/ijht.34Sp0216

Murgi N., De Lorenzo G., Corigliano O., Mirandola F.A., Fragiacomo P., 2016, Influence of anodic gas mixture composition on solid oxide fuel cell performance: Part 2, International Journal of Heat and Technology, 34(S2), S309-S314, DOI: 10.18280/ijht.34Sp0217

Özkan G., Gemici S., Başarır E., Özkan G., 2016, Determination of optimum production conditions of casting slurry in the manufacture of molten carbonate fuel cell electrodes with the tape casting technique, Chemical Engineering Transactions, 52, 871-876, DOI: 10.3303/CET1652146

Rossi R., Cavina M., Setti L., 2016, Characterization of electron transfer mechanism in mediated microbial fuel cell by entrapped electron mediator in saccharomyces cerevisiae, Chemical Engineering Transactions, 49, 559-564, DOI: 10.3303/CET1649094

Saebea D., Authayanun S., Patcharavorachot Y., Arpornwichanop A., 2016, Performance evaluation of lowtemperature solid oxide fuel cells with sdc–based electrolyte, Chemical Engineering Transactions, 52, 223-228, DOI: 10.3303/CET1652038

Sommer E.M., Vargas J.V.C., Martins L.S., Ordonez J.C., 2016, Constructal alkaline membrane fuel cell (AMFC) design, International Journal of Heat and Technology, 34(S1), S125-S132, DOI: 10.18280/ijht.34Sp0116

Sulaiman, N., Hannan, M.A., Mohamed, A., Majlan, E.H., Daud, W.W., 2015, A review on energy management system for fuel cell hybrid electric vehicle: Issues and challenges. Renewable and Sustainable Energy Reviews, 52, 802-814.

Tippawan P., Arpornwichanop A., 2016, Maximizing the efficiency of a heat recovery steam generator for solid oxide fuel cell-based trigeneration systems, Chemical Engineering Transactions, 52, 1051-1056, DOI: 10.3303/CET1652176

Torreglosa, J.P., Garcia, P., Fernandez, L.M., Jurado, F., 2014, Predictive control for the energy management of a fuel-cell–battery–supercapacitor tramway. IEEE Transactions on Industrial Informatics, 10(1), 276-285.

Washing, E., Pulugurtha, S., 2015, Well-to-wheel analysis of electric and hydrogen light rail. Journal of Public Transportation, 18(2), 74-88.

Wiranarongkorn K., Im-Orb K., Ponpesh P., Patcharavorachot Y., Arpornwichanop A., 2017, Design and evaluation of the sorption enhanced steam reforming and solid oxide fuel cell integrated system with anode exhaust gas recirculation for combined heat and power generation, Chemical Engineering Transactions, 57, 97-102, DOI: 10.3303/CET1757017

Xu, L., Ouyang, M., Li, J., Yang, F., Lu, L., & Hua, J., 2013, Application of Pontryagin's Minimal Principle to the energy management strategy of plugin fuel cell electric vehicles. International Journal of Hydrogen Energy, 38(24), 10104-10115.

Zhang, W., Li, J., Xu, L., Ouyang, M., Liu, Y., Han, Q., & Li, K., 2016, Comparison study on life-cycle costs of different trams powered by fuel cell systems and others. International Journal of Hydrogen Energy, 41(38), 16577-16591.

Ziogou C., Giaouris D., Papadopoulou S., Voutetakis S., 2016, Supervisory control and monitoring of a hybrid high temperature pem fuel cell system with li-ion batteries and an lpg reformer, Chemical Engineering Transactions, 52, 1021-1026, DOI: 10.3303/CET1652171