TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol.12, No.2, February 2014, pp. 1094 ~ 1099
DOI: http://dx.doi.org/10.11591/telkomnika.v12i2.4410

Summarize of Electric Vehicle Electric System Fault and Fault-tolerant Technology

Zhang Liwei[1]*, Huang Xianjin[1], Yang Yannan[1], Xu Chen[1], Liu Jie[2]
[1]School of Electrical Engineering, Beijing Jiaotong University, Beijing 100044, China
[2]State Key Laboratory of Automotive Simulation and Control, Jilin University, Jilin 130022, China
*Corresponding author, e-mail: lwzhang@bjtu.edu.cn, zhanglw_ee@126.com

Abstract

Electric vehicle drive system is a multi-variable function, running environment complexed and changeable system, so it's failure form is complicated. In this paper, according to the fault happens in different position, establish vehicle fault table, analyze the consequences of failure may cause and the causes of failure. Combined with hardware limitations, and the maximum guarantee system performance requirements, passive software redundancy fault-tolerant strategy is put forward, give an example to analysis the pros and cons of this method.

Keywords*: electric drive system, failure analysis, fault tolerant technology*

1. Introduction

Electric drive system is the centre of electric vehicles, electric drive systems usually determines electric cars running in the best way and protects the motor proper function in any work environment. Due to the long running, environmental factors and man-made improper operation and other reasons, the electric drive system may has various problems, and any failure could further expand thereby affecting the safe operation of the vehicle, so timely, reliable and fast detection the failure occurs where the drive system happens, and take the appropriate fault tolerance strategy to maintain the basic operation of electric vehicles is valued for more and more domestic and foreign scholars [1-3].

It is important to accurately determine the fault location and adopt a reliable fault diagnosis technology timely for the electric drive systems, take a appropriate fault tolerant control strategy is also crucial. In this paper, presenting the failures may happen at electric drive system in details, and summarizes the possible fault-tolerant strategy can be used in view of the different fault [4].

2. The Electric Drive System Failure of Electric Vehicle

2.1. The Fault Type of Electric Drive System

Electric vehicle drive system is a complex system, and fault type varied, according to the location of failure, it can be divided into five specific failure: motor failure, motor controller failure, failure between motor controller and motor lines, motor power supply failure, and the motor system communication failure [5]. Establish the fault table according to the specific location of failure happening as following.

Table 1. Fault of Abnormal Motor Operation

Fault symptom	Failure position Ⅰ	Fault identification number
Motor doesn't run properly	Motor controller failure	A
	Motor controller to line failure	B
	Motor failure	C
	Electrical system power supply failure	D
	Motor system CAN communication failure	E

Received August 17, 2013; Revised September 11, 2013; Accepted October 12, 2013

Table 2. Fault of Motor Controller

Fault identification number	Failure position Ⅱ	Failure position Ⅲ	Failure position Ⅳ
A	Inverter unit failure	Filtering in addition to unit failure	The failure of the bus Capacitor failure
		On high voltage power unit failure	Charging relay failure The main relay failure Charging resistance fault
		Inverter circuit failure	Auxiliary power failure Power device failure
	The control unit failure	Sensor unit failure	Current sensor failure Temperature sensor failure
		Auxiliary power failure	

Table 3. Fault of Circuit between Motor Controller and Motor

Fault identification number	Failure position Ⅱ
B	A short circuit Open circuit

Table 4. Fault of Motor

Fault identification number	Failure position Ⅱ	Failure position Ⅲ	Failure position Ⅳ
C	Cooling failure	Pump failure Water failure	
	Failure of the stator	The stator core	Loose core Local overheating
		The stator winding	Interturn short circuit Insulation damage
	Rotor fault	Stents craze Don't balance	
	Bearing failure	Vibration The temperature is too high Charged	

Table 5. Fault of Power of Drive System

Fault identification number	Failure position□	Failure position□	Failure position□
D	High voltage direct current power supply failure	High voltage battery failure High voltage power supply wiring fault	A short circuit Open circuit
	Low voltage dc power supply	Low voltage battery failure Low voltage power supply wiring fault	A short circuit Open circuit

2.2. The Consequences of Failure

2.2.1. Motor Controller Failure

Motor controller is the centre of the electric drive control system, which achieve a normal operation through variety of signal acquisition, operation and transmission to.

(1)、Inverter unit failure: The inverter unit is mainly to complete normal supply to electric drive system and implementation of control strategies tasks. High power unit failure will not be able to ensure the normal power-up, so the system may not start properly. Filtering energy storage unit provide a stable working voltage support to the system continues running, when the main circuit under-voltage, it's easy to cause the motor output power reducing, the current increasing, over current severely can cause burning IGBT; When the main circuit over-voltage, it will cause bus capacitor or IGBT breakdown.

(2)、Control unit failure: sensors is an important part of the motor controller, normally, the sensor will collected motor operating parameters and the temperature signal and fed them to the signal processor, then to make the machine run normally and to protect the motor through the signal processor operation control or protection. Once the current or speed sensor faults, it will cause the motor system out of control; If temperature sensor failure, the system will not be

able to obtain the correct motor temperature signal, It may cause motor heating even burned an important component at a prolonged abnormal operation [6, 8].

2.2.2. The Motor Fault

Stator winding fault, turn to turn short-circuit and insulation burned, may cause winding burned and torque fluctuations; Motor stator core fault, core loosening and local overheating will result in no-load current increases, and the vibration and noise increase; Rotor fault , brackets cracking and rotor eccentricity produces unbalanced magnetic pull, will cause vibration, friction between the rotor and the stator, resulting in damage to the motor; Bearing failures also cause increased vibration. When cooling system failure, the motor itself and some of the key positions within the drive system temperature increase, and the device can cause electrical damage and other damage, affecting the normal operation of the motor.

2.2.3. Motor system CAN communication failures

Electric vehicle motor system command execution and system status feedback through CAN communication transmission, when CAN communication transmission path or short circuit fault occurs, it will affect the signal transmission, the motor controller can't working properly; CAN communication signal transmission by electromagnetic interference or send the wrong signal, the control system may give the wrong motor control signal, causing the motor can't running properly [5, 7].

2.3. The Causes of Failure

In addition to long-time use, the oscillation and fever causes wear and tear throughout the inside of the motor, burning and other unavoidable cause of the fault, there are some of the possible reason of trouble:

(1) Overpressure

Overvoltage failure generally occurs in the vehicle charging, mainly concentrated in the DC bus voltage. After the normal charge, pre-charge circuit is not disconnected and the control of its internal voltage detection circuit fails, the detected voltage signal is too large, the protective action will cause an overvoltage. Overvoltage fault not only affect the device insulation, can also cause damage to the device.

(2) Under voltage

Undervoltage generally occurs in electric cars electric working conditions. Usually high-voltage battery voltage is too low, the pre-charge circuit is not removed after the end of the normal charge and control of its internal voltage detector failure will lead to power supply voltage. Brown will affect the system performance of the play, but also cause damage to the device, when the system the same power output, the voltage is too low will inevitably cause excessive current beyond the device's operating range, causing damage to the device. The motor, the undervoltage work efficiency will reduce severe fever, prolonged undervoltage work will result in damage to the motor [9].

(3) Over current

Generally occurs in the DC bus current and the motor AC output terminal sections. Motor running when the current exceeds the rating, and beyond the large magnitude, will form a great impact on current threats to the internal components of the motor and system security. Overcurrent generally occurs due to a DC link busbar insulation damage, resulting in positive and negative short-circuited; unbalanced three-phase stator winding, three-phase short circuit between the windings, causing the line current is too large; controllers internally detect partial failure detection out of the current signal is too large and thus protected.

(4) Overload

Motor is running, the current exceeds the rating, but exceeded marginally. Mainly due to mechanical overload overloaded, resulting in motor heating, three-phase current is too large; stator winding phase unbalance, imbalance of a three-phase winding phase operation current is too large, uneven heat; controller current detection section fails, the detected current signal is too large, resulting in protection.

(5) Over temperature

Normal temperature operation is to ensure security of the system, the body temperature will affect the motor insulation and motor controller to work properly. Usually caused by overheating the main reasons are: the system is overloaded long running state; motor controller

switching losses and the thermal effect of the motor winding currents cause the system temperature is too high; motor stator and the winding phase imbalance, cause a short circuit or open circuit is too large currents caused by the thermal effect of current under high temperature.

(6) Communication failures

Communication circuit complete motor running condition signal and the control signal transmission, the communication system failure signal can't be transmitted timely, resulting in motor disorders, severe error propagation signal, will cause the controller malfunction, the error signal is given. The major causes of communication system failures: CAN communication cable is broken, the vehicle is running or vibration causes the signal to break loose connectors; electromagnetic interference caused by CAN communication line transfer signal change, and the positive impact of the instruction execution system state detection stubble [8-10].

2.4. Fault Diagnosis of Electric Drive System

With electronic control system complexity increases, the reliability of the system put forward higher requirements. Electric drive system fault detection, diagnosis and fault-tolerant technology improve the system reliability and maintainability, and get more and more attention. The 1970s to the early 1980s as a simple electronic control system, the fault type is relatively small, generally using a simple diagnostic instruments to do the test, and the system reliability is relatively higher. To the 1980s to the late 1980s, the development of technology, electric drive systems have some slightly more complex control functions, then there has been more powerful fault diagnostic apparatus, capable of more complex systems for fault analysis. Up to now, since the development of automatic control theory, diagnostic technology continues to improve, then there is more intelligence and information-based diagnostic mode.

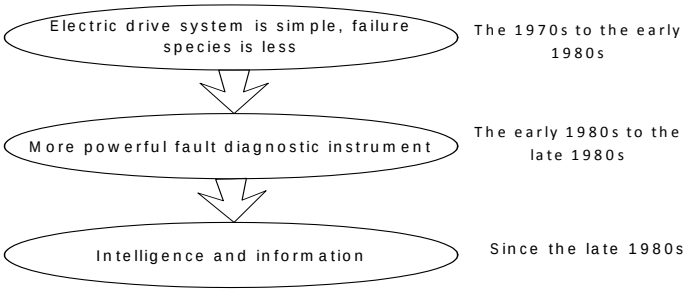

Figure 1. Development of the Fault Diagnosis

Electric drive system is a large and complex system, when a fault occurs, the controller is able to accurately detect the location and cause of failure, we must rely on the sensor detects the amount of quantitative analysis to characterize it. When a fault occurs, you can press the method shown in Figure 2 diagnostic analysis. Voltage and current through the sensor, and then the detected value by Fourier transform analysis, wavelet analysis, the stator current spectrum analysis and expert system for fault diagnosis method, etc., and then determine the type and location of failures in the PC interface displays out.

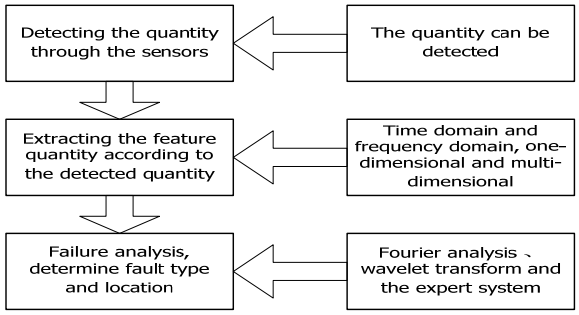

Figure 2. Method of the Fault Diagnosis

2.3. Fault-tolerant Technology of Electric Drive System

Fault-tolerant technology (Fault-Tolerant) refers to the use of certain techniques, the system fails to take appropriate measures to ensure that the basic system performance. Fault tolerant control can be divided into passive and active fault tolerant control control, passive fault tolerant control refers to the system may be expected malfunction analysis, the appropriate treatment method, when a fault is detected, the switch to the corresponding tolerance policy, usually part of the system at the expense of performance for the price; active Fault Tolerant Control is a system for real-time online monitoring, the monitoring of the failures in a timely manner to modify the parameters, or the control system for a variety of effective reconstruction, active fault tolerant low cost, fault-tolerant performance than good, but a large amount of control algorithms, the implementation process difficult and complicated [7, 9].

For the control system is usually unrecoverable fault, only by replacing some of the controller to repair the device or even the entire controller, you can use hardware redundancy fault-tolerant technology, which have several sets of control system, when a failure occurs, it is switch to another system, the hardware redundancy and high safety, easy to implement, but the cost and larger footprint; while some faults can be controlled by changing the algorithm continues to work to maintain electric drive systems, namely software redundancy.

3. Passive Redundancy Fault-tolerant Software Strategy

Passive redundant fault-tolerant software strategy for electric drive system may occur in different recoverable failure, study, rest a valid signal, the system can maintain the basic operation of the fault-tolerant strategies, and real-time computing with software programming, when the system detects a fault occurs, the switch corresponding fault-tolerant algorithms. This fault-tolerant technology lower cost to maintain the system's basic operation when a fault occurs faster response, but part of the system may be at the expense of performance for the price, and the switching process will generate a short pulse.

Usually a fault tolerance strategy is a solution for the whole control algorithm or switching. For example, the magnetic field oriented vector control with good torque control characteristics, is the normal condition of choice for electric vehicle induction motor control strategy, in order to obtain high-precision torque control, AC drive system to be set four kinds of sensors: Position Sensor detect motor speed for vector control; phase current sensor acquisition phase current signal for feedback control and the rotor flux angle calculation; DC current sensor for inverter current protection; inverter DC voltage sensors for voltage protection and regulation.

When the position sensor fails, consider speed sensorless vector control strategy, the real-time detection speed control mode is switched to speed estimation algorithm, and by synovial technology can overcome motor parameter estimation of the impact of change on the speed, improve system robustness sex.

When the phase current sensor failure, if the DC current sensor is still working, you can switch to the use of the control algorithm direct current reconstruction phase current control strategy. And when the position sensor and the phase current sensor fails, you can also take the above two fault-tolerant strategies to maximize the maintenance of motor drive system performance.

When only the position sensor is normal, the rotor field oriented vector control is not possible, then the overall control algorithm can be switched to scalar control, but the scalar control methods cannot achieve dynamic decoupling control system can maintain basic operations, performance will be the degradation [9-11].

When only the DC voltage sensor to work properly, the system can be switched into the control algorithm laugh V/f control, the dynamic performance of this control method has decreased, the electromagnetic torque transients greater impact.

Through effective signal signal reconstruction or switching system overall control strategy to ensure that the majority of cases of failure to achieve fault-tolerant technology to maximize the performance of maintenance of motor drive system, driving performance is bound to decline, but you can guarantee failure occurs crisis such as a sudden stop operating personnel safety happen.

5. Conclusion

Through effective signal signal reconstruction or switching system overall control strategy to ensure that the majority of cases of failure to achieve fault-tolerant technology to maximize the performance of maintenance of motor drive system, driving performance is bound to decline, but you can guarantee failure occurs crisis such as a sudden stop operating personnel safety happen.

References

[1] HF Yu, ZQ Liu, SM Cui. The electric car motor drive system fault and failure mode analysis. *Power electronic technology*. 2011; 45(12): 69-71.
[2] WG Fan, Y Zhao. Three-phase asynchronous motor common failures and analysis. *Mechanical management development.* 2009; 24(4): 54-55.
[3] Nabil Hammad. Fault Diagnosis for Electric/Hybrid Vehicle Induction Motor Drive. EVS, 21[C]. Monaco. 2005: 1256-1301.
[4] Diallo D, Benbouzid ME, Makouf A. A Fault-tolerant Control Architecture for Induction Motor Drives in Automotive Applications. *IEEE Trans. On Vehicular Technology*. 2004; 53(6): 1847-1855.
[5] ZQ. Liu. Hybrid cars use motor driven system fault diagnosis and fault-tolerant technology research. *Marina Industry University*. 2010.
[6] Jinbao He, Xinhua Yi. Backstepping decentralized fault tolerant control for reconfigurable modular robots. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(7): 3508-3516.
[7] Chen Xiang-Yi, Li Fei. Fault-tolerant method for detecting coverage holes of wireless sensor networks. *TELKOMNIKA Indonesian Journal of Electrical Engineering.* 2012; 10(4): 818-826.
[8] Zhou lei, Wu Ning. A joint-coding scheme with crosstalk avoidance in network on chip. *Telkomnika*. 2013.11(1):1-8.
[9] Luojiannan, LiYang. Adaptive regulation and partial failure recovery of immune network. *Telkomnika*. 2013.11(7):4054-4059.
[10] Li Zhenxing, Yin Xianggen. Architecture and fault identification of wide-area protection system. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(7): 442-450.
[11] Yongxin Feng, Tao Yang. Study of fault diagnosis method for wind turbine with decision classification algorithms and expert system. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(5): 905-910.