Mitigation strategy for AC side to suppress CM current flowing on DC cables of the motor drive system

Li Zhai\textsuperscript{a,b,*}, Liwen Lin\textsuperscript{a,b}, Chao Song\textsuperscript{a,b}, Xinyu Zhang\textsuperscript{c}, Hongtao Gu\textsuperscript{d}

\textsuperscript{a}National Engineering Laboratory for Electric Vehicles, Beijing Institute of Technology, Beijing 100081, China
\textsuperscript{b}Collaborative Innovation Center of Electric Vehicles in Beijing, Beijing Institute of Technology, Beijing 100081, China
\textsuperscript{c}Beijing Institute of Radio Metrology and Measurement, Beijing 100054, China
\textsuperscript{d}Key Laboratory of Vehicle Transmission, China North Vehicle Research Institute, Beijing 100072, China

Abstract

The electromagnetic interference of the motor drive system has a great influence on the performance. For the motor drive systems, the interference of CM current is important cause of conducted emission. AC side of motor drive system is high voltage and load is large inductive motor, so the AC side has a big impact on the DC side in the process of rapid on-off devices. The CM EMI current paths at frequency 30MHz are analyzed based on the distribution parameters of elements in current flowing circuit. The change of the CM EMI current will be analyzed through circuit and equation of the CM EMI current when the AC cable is added ferrite chokes or ferrite. The DC conducted emission electromagnetic interference suppression effect is obvious to add ferrite chokes or ferrite the AC cable in high frequency in the experiment, which is consistent with theoretical analysis. The results show that adding ferrite is more effective measure than adding ferrite choke to suppress the DC side conduction emission electromagnetic interference both in decreasing amplitude and larger frequency band.

Keywords: motor drive system; electromagnetic interference(EMI); CM current; mitigation strategy

1. Introduction

The motor drive system is the core of the electric car system[1]. Electromagnetic compatibility is a key performance index of the motor drive system, which is very important significance to ensure the driving safety of electric vehicle and reduce or avoid breakdown[2-3]. The standards of CISPR25 and GB18655 also have mandatory requirements for conducted emission of vehicle components in vehicle. Power devices of the motor controller (such as IGBT) rapid switching is the main source of EMI from the motor drive system[4-5]. EMI source is formed by DM interference and CM interference through electromagnetic coupling transmission path[6]. For the motor drive system, the CM interference current is the main cause of the EMI conducted emission. Most of the above work focuses on the CM current path of
the motor drive system [7], however, the effect of the CM current from AC side on conducted emission from DC side has not been studied. The CM current effect of the AC side on DC side will be studied. The equivalent circuit model is constructed, and the mitigation strategy for AC side to suppress CM current flowing on DC cables of the motor drive system is presented.

<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>Description</th>
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<tbody>
<tr>
<td>CM</td>
<td>common-mode</td>
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<tr>
<td>DM</td>
<td>differential-mode</td>
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<tr>
<td>IGBT</td>
<td>insulated gate bipolar transistor</td>
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<tr>
<td>LISN</td>
<td>line impedance stabilization network</td>
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<tr>
<td>AC</td>
<td>alternating current</td>
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<tr>
<td>DC</td>
<td>direct current</td>
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2. Experimental platform and test

Fig. 1 (a) shows test platform for CM current flowing on the DC cables of the motor drive system. The motor controller with 24 V DC input connects to a 100W permanent magnet synchronous motor (PMSM). The measured EMI voltage and CM current can be picked up by any one of the LISN impedance connected to an EMI receiver and a high frequency current probe, as shown in Fig. 1. It can be seen that there are two larger peaks of the CM interference current at 5 MHz and 30 MHz. The effect of EMI from the AC side on the CM current flowing on the DC side of the motor drive system at 30 MHz is studied.

![CM current experiment](image)

**Fig.1.** CM current experiment (a) CM current of the DC side test set up; (b) CM current of the DC side

3. Path analysis and the equivalent circuit

Due to the symmetry of three-phase bridge arms in the motor controller, The CM emission from the phase node P of two IGBTs of one phase bridge arm can be equivalent to a CM voltage source \( U_{CM} \) between the phase node P and chassis as shown in Figure 2(a), where, \( S_1-S_6 \) represent six IGBTs in inverter, \( C_1-C_6 \) represent the distributed capacitance between the collector and emitter of \( S_1-S_6 \); \( C_{Y1} \) and \( C_{Y2} \) represent the filter Y capacitors between positive/negative DC cable and chassis; two LISNs can be represented by the circuit composed of \( R_{L1}, C_{L1}, R_{L2}, C_{L2} \); \( C_7, C_8, C_9 \) and \( C_{10} \) represent the distributed capacitance from the IGBT phase node to the chassis; \( C_{10} \) represents the distributed capacitance between chassis and motor; \( L_M \) represents the inductance of motor phase winding. Five CM current branches in
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