

## Common Mode EMI Measurement Method of Coal Mine Inverter

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**Abstract.** For the neutral point not grounded characteristics of underground power supply system in coal mine, this paper studied common mode equivalent circuit of underground PWM inverter, and extracted parasitic parameters of interference propagation path. The author established a common mode and differential mode model of underground inverter. Taking into account the rise time of PWM, the simulation results of conducted interference by Matlab software is compared with measurement spectrum on the AC side and motor side of converter, the difference is consistent showing that the proposed method has some validity.

**Keywords:** Underground PWM inverter, common mode, conducted interference, coal mine.

### 1. Introduction

PWM drive system for its saving energy, simple maintenance and easy adjustment becomes more and more widely used in coal mining enterprises. As a result of using high-speed switching devices such as IGBT, MOSFET, which could speed up the converter dynamic response time, on the other hand, these high-speed switching power devices makes voltage and current significant changes in very short time, thus the current and voltage signal contain a wealth of high harmonics, which frequency range could be a few kHz to tens of MHz, and the magnitude may have far exceeded the limit prescribed by EMC standards. Underground converters such as electric locomotive, electric shearer produced strong electromagnetic interference, their high harmonic noise include both conducted and radiate interference. Compared to radiate interference, conducted interference could spread to far distance [1]. Therefore conducted interference is the main form of current noise in electrical equipment. Electromagnetic interference generated by inverter not only affects working of out load and shorten its life, but also brought great harm to converter itself.

### 2. An Inverter Interference Propagation Path

The inverter drive system includes two power conversions: AC / DC rectifier and DC / AC inverter. Therefore, regardless of differential mode or common mode interference exist two noise sources: rectifier bridge source and inverter source. Interference propagation path is given by dotted line as shown in Figure 1. Conducted interference generated by converter can be divided into differential mode (DM) noise and common mode (CM) interference, when the inverter circuit using a differential mode filter, common mode EMI dominates conducted interference.

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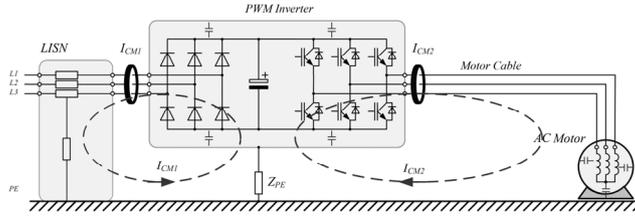


Fig. 1 Two main path of common mode current in PWM drive System

### 3. Common mode Interference Test Program

As shown in Figure 2, CISPR standard specifies measurement arrangement of PWM inverter to test conducted interference.

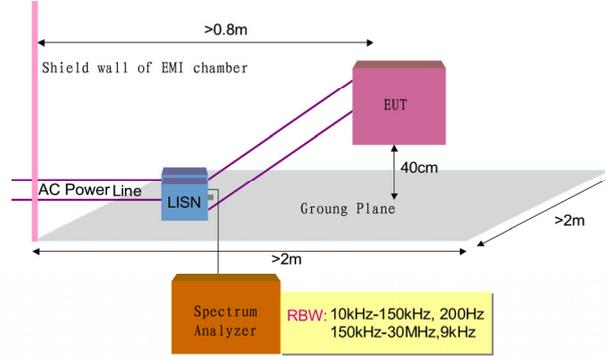


Fig. 2 CISPR standard specifies test methods

In accordance with requirements of EMC standard EN55014-1, we need a  $1\text{m} \times 2\text{m}$  aluminum plate as reference ground, linear impedance stabilization network (LISN) connected to the aluminum plate, and heat sink of PWM inverter must also connected with ground plate[2]. LISN has two main functions:

- ① provide equipment under test (EUT) a stable  $50\Omega$  impedance to ensure the comparability of experimental results;
- ② reduce power interference on experimental results.

To analyze the interference propagation path, set up a common mode equivalent circuit model as shown in Figure 3. Where  $C_{rp}$  is parasitic capacitance between heat sink and rectifier diodes;  $C_{ip}$  is parasitic capacitance between heat sink and IGBT collector;  $R_{c1}$  and  $L_{c1}$  are resistance and inductance of input cable;  $R_{c2}$  and  $L_{c2}$  are resistance and inductance of output cable;  $L_{b1}$  and  $L_{c3}$  are distributed inductance of DC bus;  $Z_{mCM}$  is common mode equivalent impedance of motor. If neglecting rectifier switching mode, any time only two diode conducted, LISN is equivalent to  $25\Omega$  in common-mode propagation path.

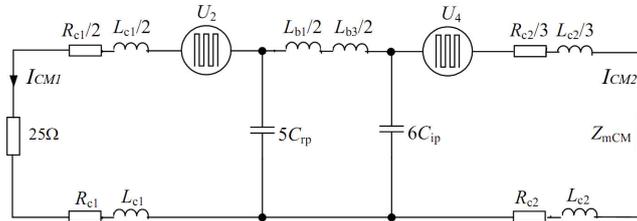


Fig. 3 High frequency circuit models of common mode interference

As shown in Figure 3, using spectrum analyzer R&S ESIB26 we measured interference sources  $U_2$  and  $U_4$  of rectifier and inverter, with impedance analyzer Agilent 4294A measured cable parameters, motor parameters and parasitic capacitance, in the end we obtain the whole interference propagation path, detailed experimental method is described in [3]. Having interference source and propagation path, the response in propagation path can be obtained by transfer function, that is, the noise measured at LISN is  $25 \cdot I_{CM1}$ .

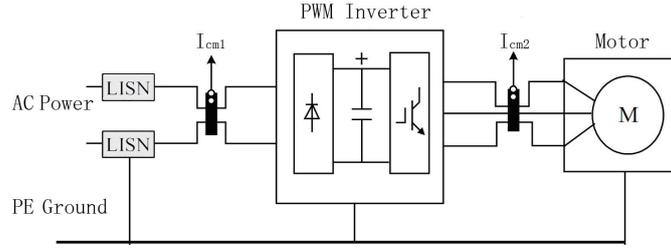


Fig. 4 Layout of Conducted EMI test

Using current probe measured current interference of EUT to power line, we could make a direct measurement of EMI noise in normal state of EUT, without contacting EUT and not changing circuit structure. Current probe having a round structure, which can easily enclose wires under test. The core part of current probe is a ferrite toroidal core [4]. When current probe wraps a wire, wire under test is equivalent to one turn of primary coil, N-turn coil around the core is the secondary coil, which can measure current value.

Conducted interferences can be measured by HF current probes. When utilized magnetic probe with toroidal shape, proper wire arrangement can be used to evaluate CM current components. Figure 4 shows wire arrangements for 3-wire and 2-wire systems respectively. Thus, CM currents are mostly calculated directly without additional analog circuitry which could limit measurement bandwidth [5].

For two-line system (DC side), common mode current is defined as the  $i_{CM1}$ , as follows:

$$i_{CM1} = \frac{i_{L1} + i_{L2}}{2} \quad (1)$$

For three-wire system (AC side) common mode current is defined as expression of phase current  $i_{L1}$ ,  $i_{L2}$ ,  $i_{L3}$ :

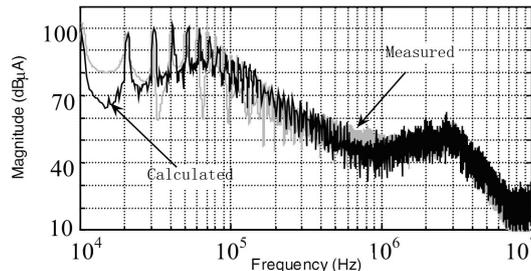
$$i_{CM2} = \frac{i_{L1} + i_{L2} + i_{L3}}{3} \quad (2)$$

When need to use current probe measuring conducted interference, the current probe output connected to spectrum analyzer, the value measured by current probe adding conversion factor is the magnitude of interference current [6]. For the same device, results can be voltage values measured at LISN 50Ω resistor and can also be current values measured with current probe on the wire, the conversion relationship is:

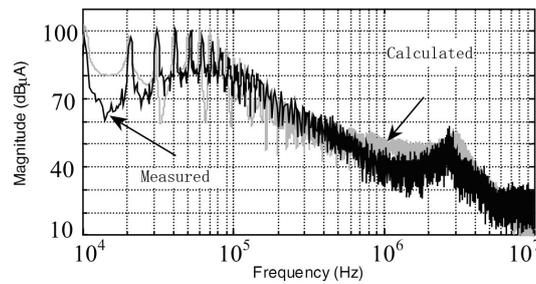
$$V(dB\mu V) = I(dB\mu A) + 20 \lg 50 \quad (3)$$

## 4. Measurement Results

In this paper, an industrial product PowerFlex700S inverter driven motor system is chosen for a experimental test. Figure 4 shows conducted EMI current testing methods: Converter line voltage is 390V/50Hz, switching frequency 10 kHz, modulation ratio 0.8. Motor rated parameters are 380V/50Hz, 22kW, 1480r/min. Current probe is Solar9209-1, EMI receiver is HP4195A, and test bandwidth is 1 kHz.



(a) Common mode current of  $I_{CM1}$



(b) Common mode current of  $I_{CM2}$

Fig. 5 Experimental and computational results of CM current

Figure 5 shows calculated results and experimental results. It can be seen in 100 kHz ~ 10MHz, around main harmonic and the resonant frequency, the difference between calculated spectrum and experimental spectrum is less than 6dB, which can meet the design requirement, proving that the conducted interference modeling method proposed in this paper has a good accuracy.

## 5. Conclusion

This paper studied conducted interference of an underground PWM motor drive in coal mine, extracted parasitic parameters of propagation path, considered common mode and differential mode EMI, using approximation method of high-frequency interference model to ensure the accuracy of simulating conducted EMI at power side and load side of PWM drive system.

## 6. Acknowledgment

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