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Conductive EMI noise measurement for switched reluctance drive

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Abstract

The component parts of the tested four-phase Switched Reluctance drive are described with the four-phase 8/6 structure double salient reluctance motor, the four-phase asymmetric bridge power converter and the 89C52 MCU digital controller. The conductive electromagnetic interference noise measurement equipment is described with the function of separated common-mode noise and differential-mode noise. The tested results of common-mode noise and differential-mode noise of the tested Switched Reluctance drive are presented and the tested results of frequency spectrum are given.

Key Words: *Switched reluctance, EMI noise, motor control.*

1. Introduction

The Switched Reluctance drive, which is made up of the reluctance machine, a power converter and controller, has advantages in that it exhibits high starting torque with low starting current, and high fault tolerance capability. It can be operated by following minimum reluctance. The supplied current waveform, the phase current waveform the supplied voltage waveform and the phase voltage waveform are not sinusoid [1, 2]. It can be used for mining machines [3, 4], starter/generator systems in automobiles [5] and aviation [6], electric vehicles [7], fan, pump, servo drive, and wind power generator systems [8–10]. The main impediment of the Switched Reluctance drive in applications is the electromagnetic interference it generates. So as to shield against the EMI, the power converter and controller are placed within metal shells. The shell of the Switched Reluctance machine is also metal.

Even with shielding, the EMI leaks via the conductive supply leads is a major source of noise. The conductive EMI noise from the Switched Reluctance drive is caused by the no sinusoid supply power from the power converter to the reluctance machine. The EMI can effect the operation of other electrical equipments via the supply leads. As such it is important to develop equipment for measurement of conductive electromagnetic interference noise from Switched Reluctance drives.

2. Structure of system

The tested Switched Reluctance drive is a four-phase Switched Reluctance motor drive, and is made up of the four-phase 8/6 structure double salient reluctance motor, the four-phase asymmetric bridge power converter and the digital controller. The cross section of the four-phase 8/6 structure double salient reluctance motor is shown in Figure 1. There are 8 poles in the stator, and there are 6 poles in the rotor. It has one centralized coil in each stator pole; no winding, no magnet and no brushes are used in the rotor. The main circuit of the four-phase asymmetry bridge power converter is shown in Figure 2. There are 8 main switches and 8 flywheel diodes in the power converter, there are two main switches and two flywheel diodes in each phase. IGBTs are adopted for the main switches. The single AC power source is rectificated to DC supplied source by the single phase rectifier, the electrolytic capacitor is used as the filter and for energy storage.

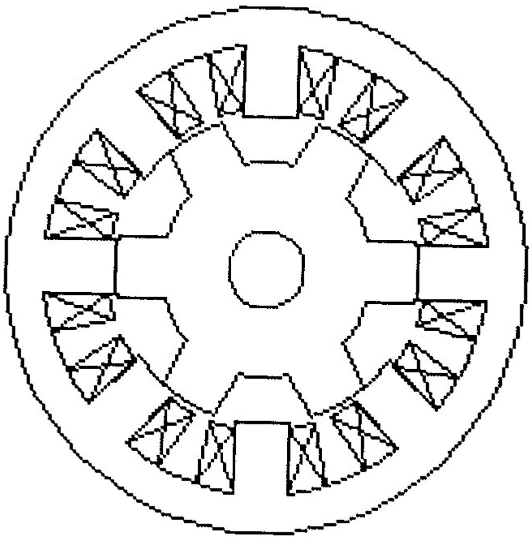


Figure 1. Cross section of the double salient reluctance motor.

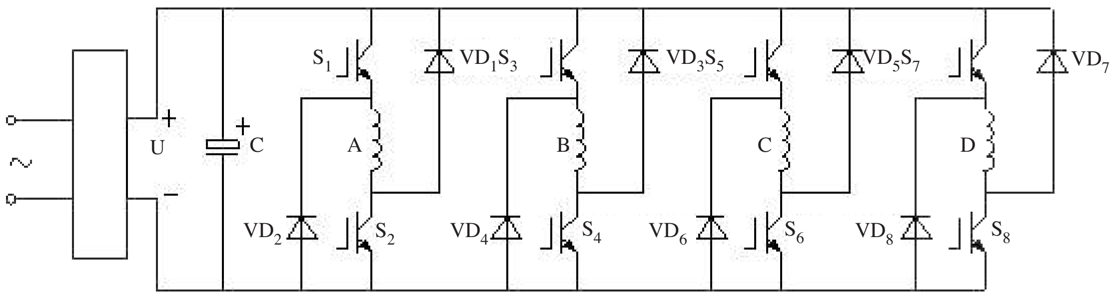


Figure 2. Main circuit of four-phase asymmetry bridge power converter.

The variable angle pulse width modulation control strategy is adopted for the closed loop rotor speed control of the developed Switched Reluctance drive. The turn-on angle of the main switches and the turn-off angle of the main switches in the power converter are fixed at the different optimum range within the different rotor speed range. The triggering signals of the main switches are modulated by the pulse width modulation signal with a certain frequency. The average supplied voltage of the phase windings is regulated by regulating the duty ratio of the pulse width modulation signal, and the average electromagnetic torque of the motor can be regulated by regulating the average supplied voltage of the phase windings. The 89C52 MCU is used as the core of the digital controller.

The photograph of the tested Switched Reluctance drive is shown in Figure 3. Here, the label **1** denotes the power converter with the 89C52 MCU digital controller, **2** denotes the constant current source for load, **3** is the torque/rotor speed instrument, **4** is the load, **5** the torque/rotor speed transducer, and **6** is the four-phase 8/6 structure double salient reluctance motor.

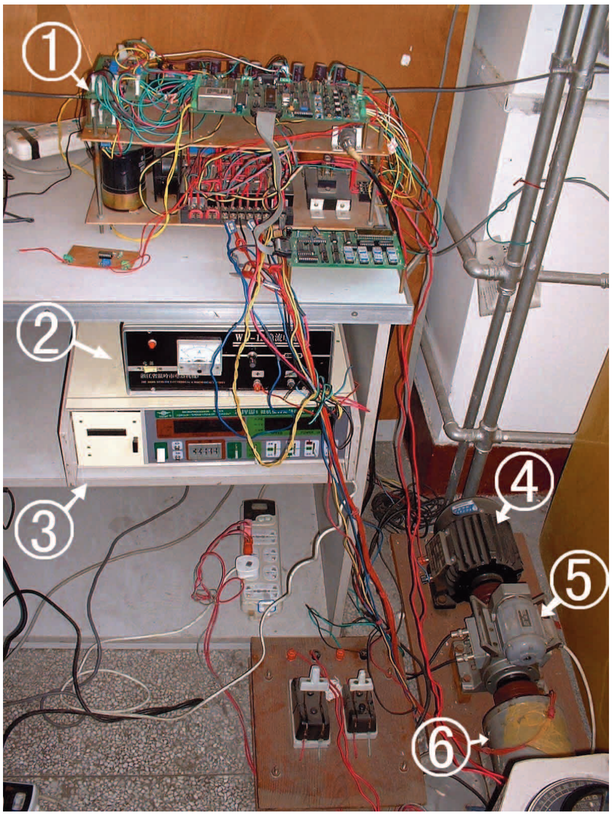


Figure 3. Photograph of the tested Switched Reluctance drive.

The schematic of the conductive electromagnetic interference noise measurement equipment is shown in Figure 4. Common-mode (CM) noise and differential-mode (DM) noise can be separated by the discrimination network, which are displayed in the spectrum analyzer. The AC side input of the Switched Reluctance drive is connected to the input of the diagnostic system.

A photograph of the conductive electromagnetic interference noise measurement equipment with the spectrum analyzer and the computer is shown in Figure 5.

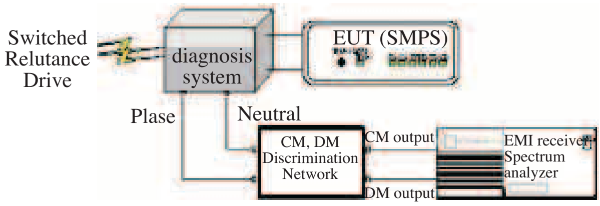
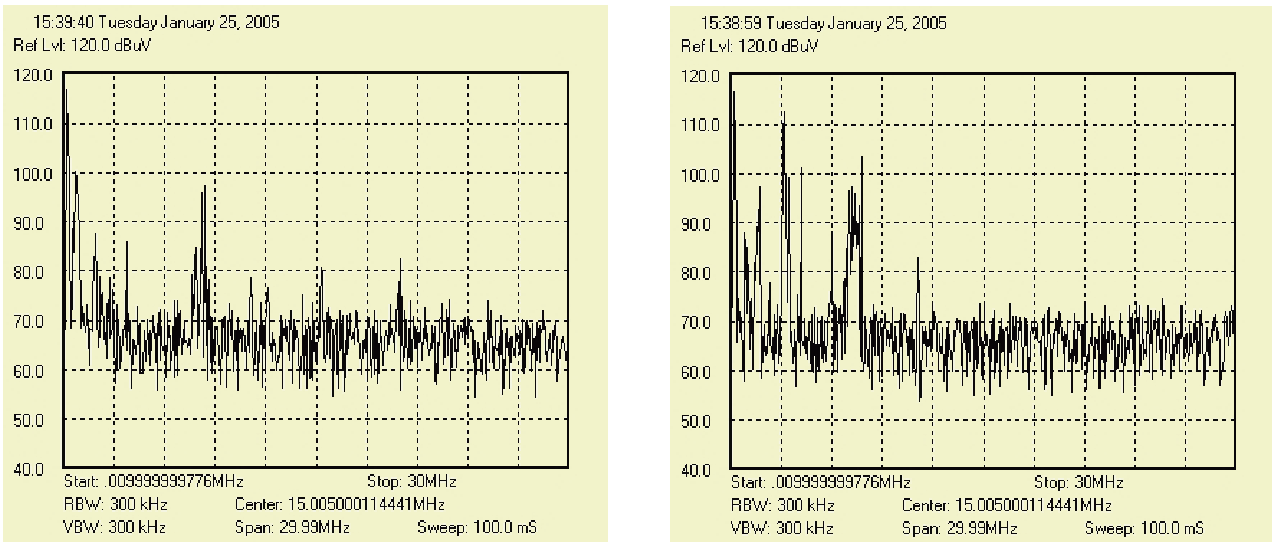


Figure 4. Schematic of the conductive electromagnetic interference noise measurement equipment.

Figure 5. Photograph of the conductive electromagnetic interference noise measurement equipment.

3. Test results

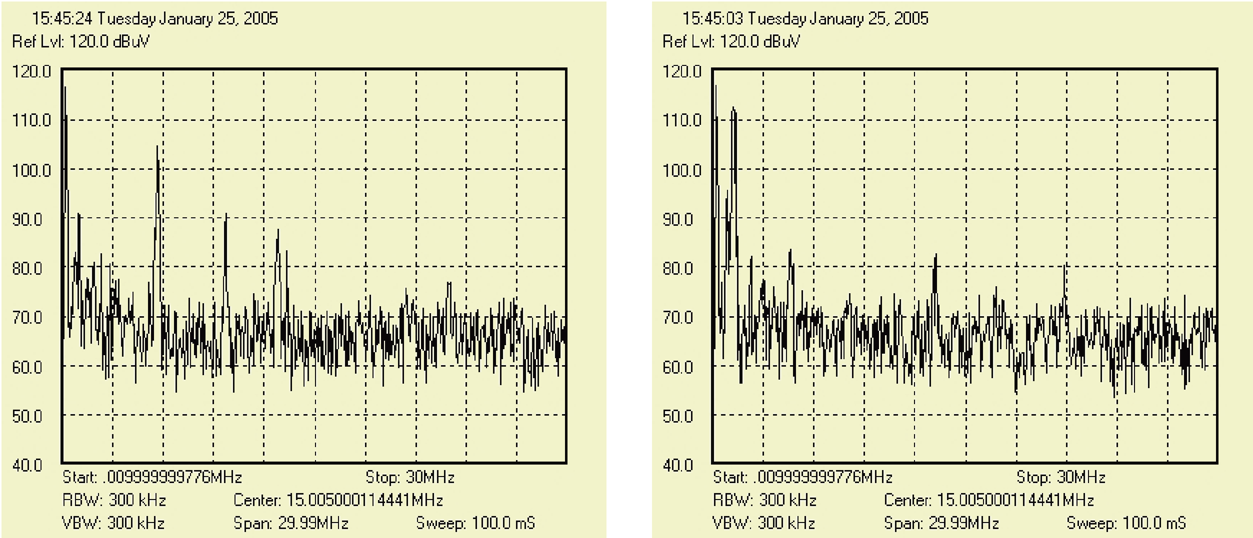
The tested results of CM noise and DM noise of the tested Switched Reluctance drive are shown in Figure 6, where the rotor speed of the motor is 407 r/min, there is no load on the motor. The tested results of CM noise and DM noise of the tested Switched Reluctance drive are shown in Figure 7, where the rotor speed of the motor is 407 r/min, the load is 0.5 N · m. The tested results of CM noise and DM noise of the tested Switched Reluctance drive are shown in Figure 8, where the rotor speed of the motor is 800 r/min, the load is 0.5 N · m.



a) CM noise

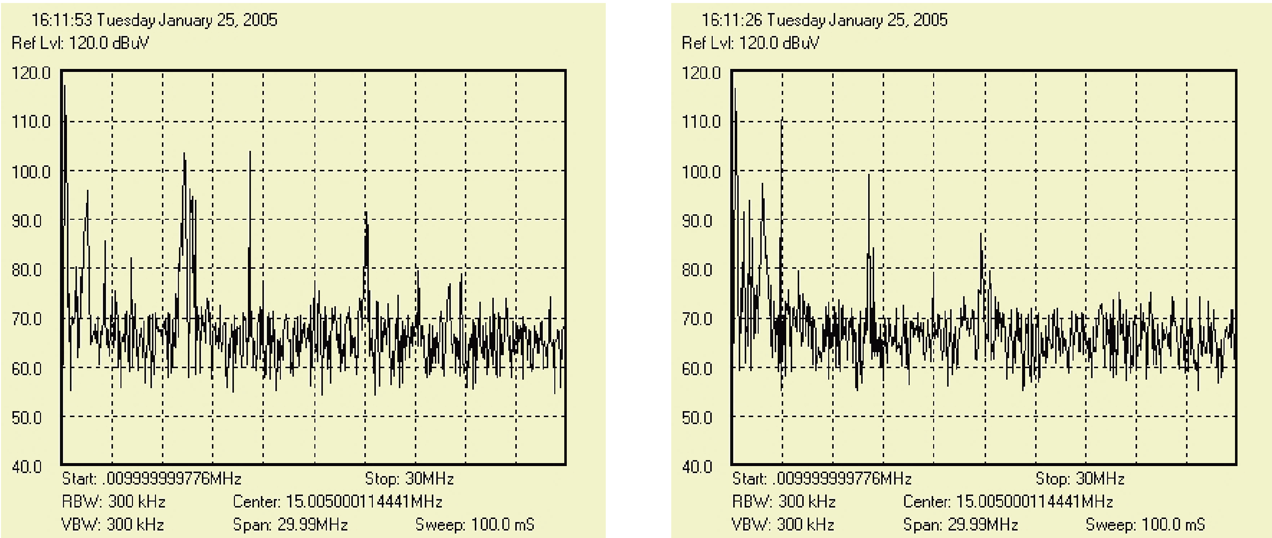
b) DM noise

Figure 6. Tested results.



a) CM noise b) DM noise

Figure 7. Tested results.



a) CM noise b) DM noise

Figure 8. Tested results.

Tested results of frequency spectrum are shown in Table 1, where the rotor speed of the motor is 407 r/min, there is no load on the motor.

Tested results of frequency spectrum are shown in Table 2, where the rotor speed of the motor is 407 r/min, the load is 0.5 N · m.

It is shown that the main parts of the CM noise and DM noise are below 30 MHz. More heavy the loads, greater is the magnitude of the CM and DM noises.

Table 1. Tested results of frequency spectrum with no load on motor.

(MH$_Z$)		**1.5**	**3**	**4.5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**14**
Magnitude	CM(dBuV)	61	58	64	72	70	98	68	56	58	60	74
	DM(dBuV)	80	70	70	88	78	68	58	64	54	72	70
Frequency (MH$_Z$)		**15**	**16**	**17**	**18**	**20**	**21**	**22**	**23**	**24**	**29**	**30**
Magnitude	CM(dBuV)	65	58	72	58	82	68	68	60	70	62	62
	DM(dBuV)	73	62	60	70	56	62	58	56	58	58	70

Table 2. Tested results of frequency spectrum with 0.5 n.m load.

Frequency (MH$_Z$)		**1**	**1.5**	**2**	**4**	**5**	**5.5**	**7**	**7.5**	**9**	**10**	**11**
Magnitude	CM(dBuV)	92	78	82	62	76	105	55	74	60	92	66
	DM(dBuV)	112	58	70	58	68	62	68	58	70	58	74
Frequency (MH$_Z$)		**13**	**13.5**	**14**	**15**	**16**	**16.5**	**17**	**18**	**20.5**	**23**	**25**
Magnitude	CM(dBuV)	88	78	72	56	72	72	58	63	66	76	58
	DM(dBuV)	73	82	68	68	74	76	64	55	80	58	73

4. Conclusion

The conductive electromagnetic interference noise is the main part in the Switched Reluctance drive. The conductive electromagnetic interference noise measurement equipment has been developed for testing the conductive electromagnetic interference noise of the Switched Reluctance drive. The common-mode noise and differential-mode noise can be separated. It contributes to design the common-mode filter and the differential-mode filter.

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