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学　位　論　文　内　容　の　要　旨

博士の専攻分野の名称　　博士（工学）　　氏名　唐 一展弋

学　位　論　文　題　名

Study of a High-Precision Analysis Method about EMI Noise for Motor Drive Systems in Inverter Air Conditioners

（インバータエアコンにおけるモータ駆動システムの高精度 EMI 解析技術に関する研究）

Following the development of electronic science and technology, more and more power electronic devices are widely applied in almost all fields. But at the same time, when these devices are working as on-off switching, they also produce serious electromagnetic noises, and these noises will impact the other electronic products through some path just like parasitic capacitance and inductance. How to solve this kind of problem results in a new discipline called electromagnetic compatibility (EMC). As people are increasingly concerned with saving energy, power electronic devices such as converters and inverters are more and more widely applied to household appliances and industrial areas, e.g., an uninterruptible power supply (UPS) uses batteries and inverters to supply alternating current (AC) power when the power supply is not available. And with high-voltage direct current (HVDC), AC power is converted to direct current (DC) power and the high voltage DC power is transmitted to another location, at the receiving location, an inverter is the key component and converts the power back to AC. Especially, the motor drive system has been changed from the industrial power direct drive to pulse width modulation (PWM) drive, PWM inverter-fed motor drive systems. But the inverters are mainly made up of power semiconductor devices, just like insulated gate bipolar transistors (IGBTs) and metal-oxide-semiconductor field-effect transistors (MOSFETs), etc. When these power semiconductor devices do high-speed switching, because of the switching time is quite short, du/dt and di/dt become considerable. It means the high-amplitude and high-frequency leakage current will occur. This kind of leakage current goes through the parasitic capacitance which exit between the devices and ground, and then it backtracks to the power supply system. This kind of noise will affect the other products in the same power system. It is called conducted electromagnetic interference (EMI) noise. Especially, the development of the modern power inverter system towards to high frequency, high efficiency, and small size, so EMI noise becomes serious.

Modern motor drive system as a kind power converter system mainly applies PWM drive method. This kind of PWM inverter-fed drive system will inevitably generate the conduced EMI problems. The conduced EMI includes common-mode (CM) interference and differential mode (DM) interference. At present, there are a lot of researches and literatures about the analysis of the harmonic components of DM voltage and research on the hazards of dv/dt. And the studies have shown that the filter capacitance and inductance can inhibit the high-frequency DM interference well. However, the parasitic capacitance exists between the semiconductor devices and heat-sinks, as well as exists between the devices and the ground such as the parasitic capacitance between the motor and ground. Because of the parasitic capacitance, high-frequency CM noise can easily go back to the power system. CM interference

is the principal part of conducted EMI and main inhibition object. Furthermore, the conduction mechanism analysis and mathematical models are the basis of EMI research. Accurate and efficient model is not only beneficial to the prediction of EMI, but also conducive to the design of filter. Therefore, in order to solve the problem of EMI, to analyze the interference mechanism and build the circuit model is a necessary step.

The research of EMI caused by inverter-fed drive system has been performed comprehensively. But all the equivalent circuits proposed before, are too complex. These equivalent circuits can well describe the characteristic of CM noise circuit, but the time of predicting the interference in the PWM inverter-fed drive motor system will greatly increase, and the cost of interference suppression will substantially increase too. Therefore, more simple, easy to understand and effective equivalent circuit model will greatly improve efficiency of interference suppression. This thesis will focus on the research about the simple and effective CM equivalent circuit in PWM inverter-fed motor drive system. Following the development of the computer science, computer-aided design and simulation tools have been widely applied in industry design and research. In this thesis, a kind of computer-aided optimization software modeFRONTIER is introduced to decide the element of CM equivalent circuit objectively and improve the accuracy. This thesis proposed a kind of π type CM equivalent circuit for inverter-fed motor drive system. At the same time, the possibility of non-linear phenomenon is discussed in inverter-fed motor drive systems. The accuracy of the simple equivalent circuit will be improved by introducing the non-linear element.

In order to protect the environment, the new refrigerant hydrocarbon (HC) and hydrofluorocarbon (HFC) is widely applied to replace the chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC). HC and HFC will lead to high permittivity, high parasitic capacitance. And high parasitic capacitance will lead to high leakage current, high EMI noise. Therefore the research about the permittivity of oil and refrigerant mixture becomes important. In order to estimate the permittivity, first it must know the parasitic capacitance when there is no oil-refrigerant mixture is in the compressor. And then, it must be known the capacitance when the motor is running. In the past, it is almost difficult to measure the parasitic capacitance between the coil and frame of motor in operation. But base on this equivalent circuit, when the motor is running, the capacitance can be confirmed. Therefore, the permittivity of mixture can be estimated.

In the past, the designer designs the product, the product is assembled, then measure the EMI noise. If the test result could not fill the EMI standard, the product will be design again. This kind of design flow will waste long time and lead to high cost. This research will improve the design process. After the design, the EMI noise can be simulated through the computer-aided software. According to the experiment test result to built the equivalent circuit and calculate the parameters through some method. At the same time, a parts library is built. According to the system connection diagram, the separate parts models can be connected to a system equivalent circuit. Then according to this system equivalent circuit it can be got the simulation result to predict the EMI noise level. This research will focus on these two points, how to build the optimized equivalent circuit and calculate the parameters and how to connect parts models together as a system equivalent circuit.