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Research progress and status quo of power electronic system integration

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ABSTRACT

Electric power is a milestone in human civilization because it pushes forward the industrial and information process of our society, and the application of electric power in our daily life is being perfected because of the development of science and technology. In the field of power electronic technology, power electronic system integration is always the hot issue. This essay introduces the concept, content, level and format of power electronic system integration and digs into the content and research direction of power electronic system integration technology.

KEYWORDS

Electric power; System integration technique; Research status and development; Layer and forms.



INTODUCETION

Electric power is the most revolutionary technology in the world and is the most valuable energy resource. Because of the exploration and application of electric power, human entered the industrialized and information-based society. We have achieved a lot in the research and application of electric power technology, but it is always our focus to make electric power more environmental-friendly and energy-saving. The appearance of power electronic technology changed our ways of using electricity. People use power electronic technology as an important indicator to evaluate the level of power application. Figure 1 shows the average level of power application world wide in recent years.

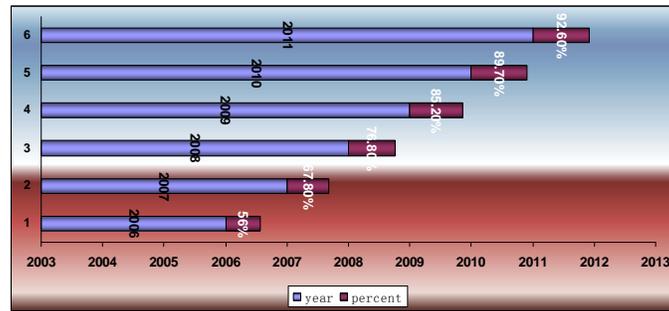


Figure 1 : Average level of power application world wide in recent years

Table one shows the new problems faced by power electronic technology, the contradiction between the complexity of power electronic technology and its wide range of application is severing. The key to this problem is power electronic system integration technology. Development of power electronic system integration technology guarantees the development of power electronic technology, and China’s economy. Figure 2 shows the distribution of China’s power integration industry.

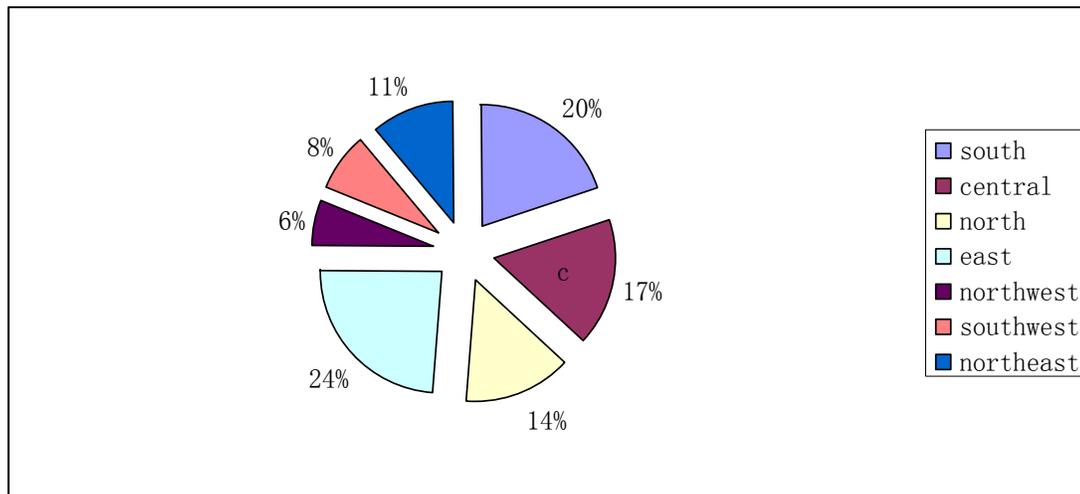


Figure 2 : Distribution of China’s power integration industry

OVERVIEW OF POWER ELCTRONIC SYSTEM INTEGRATION

The concept of power electronic integration was brought up several decades ago, and the appearance of transistor is a crucial step of the development of power electronic integration. In 1946, the first computer, ENIAC, was created in University of Pennsylvania. The vacuum tube it used had a

capacity of 18000G, and was 24 meters long, 6 meters wide, 2.5 meters high with an operating speed of 5000 times per second. The computer weighed 30 tons. The appearance and development of transistor pushed forward the development of integrated circuits. The development of integrated circuit further pushed forward the development of science and technology. The monolithic integration, which was created first by combining main circuit, drive, protective circuit and control circuit on one silicon chip, illustrated the concept of system on chip (SOC). But monolithic integration had many disadvantages, such as the difference between the manufacturing process and technique of the main circuit with high voltage and large current, and that of its circuit components with low voltage and small current, and the problem of heat transfer in the high voltage isolation. These all demonstrate that the application of monolithic integration is very difficult. So monolithic integration can only be applied to equipment of small power. Currently, equipment of large power often uses hybrid integration. Hybrid integration puts bare electronic chips of different manufacturing processes in one module, and it has been used in electric power module and intelligent power module. At about 1998, American governments, military and researchers about power electronic technology brought up the concept of Power Electronic Building Block (PEBB), which provided new orientation for the development of power electronic technology and attracted people's attention to power electronic system integration technology.

Currently, some influential institutes about power electronic integration technology are: Center for Power Electronic System (CPES), School of Electrical Engineering of Cornell University, General Electric Company, International Rectifier, Semikron Company, and ABB of Switzerland.

DIFFERENT LAYERS AND FORMS OF POWER ELECTRONIC SYSTEM INTEGRATION

The passages above have shown the development of power electronic system integration and we can see that it can be divided into 3 different layers and forms.

Monolithic integration

Monolithic integration demonstrates the concept of SOC. It uses the processing method of semiconductor integrated circuit to put the devices, drive, and control and protect circuits on one single chip. It has a high degree of integration and has been widely applied to mass production and automatic production to effectively save production costs and reduce the size and weight of devices. But it can not be applied to main circuit devices used in high voltage and large current or devices used in low voltage and small current since the processing procedures are different. Besides, monolithic integration has not overcome the problem of high-voltage isolation and heat transfer. So monolithic integration can only be used in devices of small power.

Hybrid integration

Hybrid integration combines devices, protects circuits and control circuits with different powers and different silicons in one module. This kind of integration system overcomes the disadvantages of monolithic integration, such as high-voltage isolation and heat transfer. Besides, monolithic integration has a high degree of integration, and smaller size and weight, but it also has some problems, such as the high cost and low credibility in terms of distribution parameter, electromagnetic compatibility and heat transfer. It develops towards high power. The research about hybrid integration faces the contradiction between integration and technical hurdles. Hybrid integration is the mainstream of power electronic integration technology, with Intelligent Power Module (IPM) as the most typical example.

System integration

System integration means combining current devices into a complete system by blending and packaging such as the communication power supply in electronic system. System integration is the combination of many functions. Though it has a low degree of integration and many technical problems,

however, it has been widely applied to system integration in many aspects. But because system integration has a low degree of integration. So it can not reduce the size and weight of devices, and the design and manufacture process of its devices are very complicated, so it can not show the features of integration very well. Currently, system integration is applied to systems with high power and complicate structure and functions.

RESEARCH PROGRESS AND STATUS QUO

Circuit technique of power electronic integration

Researches about power electronic integration module mainly focus on main circuits, control circuits and drive circuits which have a certain degree of general performance. The aim of studying integration module is to avoid the loss of electric power while using electricity. When people are analyzing main circuits, they would use devices as converters to guarantee the use of integration modules. Different converters have different requirements for interface communication. TABLE 1 is the requirements of different converters: (unit: MB/s)

TABLE 1 : Requirements of different converters: (unit: MB/s)

| | I1 | I2 | I3 |
|-----------------------|---------|--------|--------|
| Three-phase inverter | 80.1475 | 3.4800 | 0.0480 |
| Three-phase rectifier | 81.5858 | 4.9200 | 0.481 |

People also use soft switching circuits transferring between AC and DC, and DC/DC phase-shift full bridge circuit and half-bridge resonance circuit. Figure 3 is the circuit diagram of resonance and soft switching circuits:

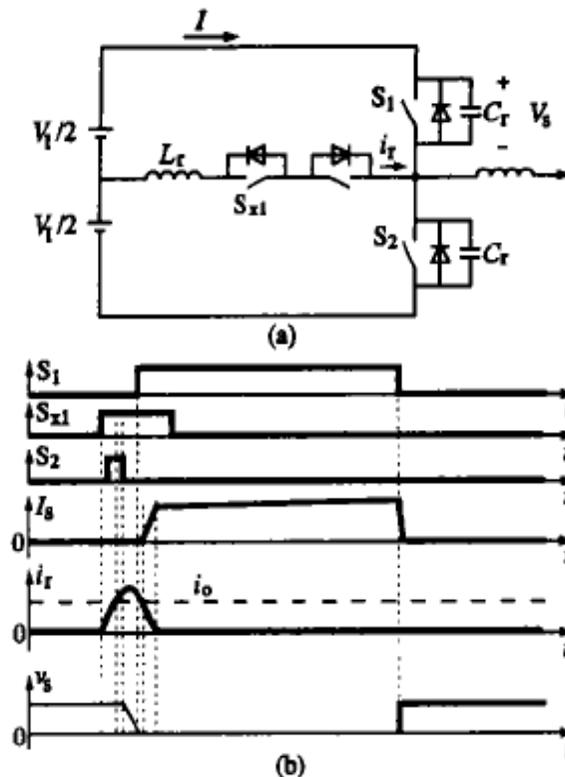


Figure 3 : Circuit diagram of resonance and soft switching circuits

The research results of drive circuit include source drive technology which can reduce the noise of witching. The research of control devices is based on repeatable programming digital circuit of DSP and EPLD.

New devices of electric power

The development of power electronic integration technology demand innovation and invention. The research about new devices, which focuses on the improvement of Sic devices and Si devices, is an important direction of power electronic system integration. Progress has been gained by researchers' efforts: the wastage and calorific value of devices have been effectively reduced, cooling equipment has been improved.

Packaging technique of power electronic integration module

China mainly uses hybrid integration to analyze power electronic integration, so we have to dig deep into the packaging technique of integration module. Aluminum wire bonding technology, which is easy to operate and has lower costs, is an important technology of integration module. But aluminum wire bonding technology also has many disadvantages: firstly, the area of boning pad is small, speed of transferring heat is slow, heat is concentrated and can cause the damage of chips because of local overheating. Secondly, the current is concentrated, which can cause the electrical-over-stress of switches. Thirdly, the distribution of current between aluminum wires is uneven which can cause the concentration of current in certain areas. Fourthly, many problems would arise when conducting bonding. Figure 4 shows the temperature field of aluminum wire bonding chips.

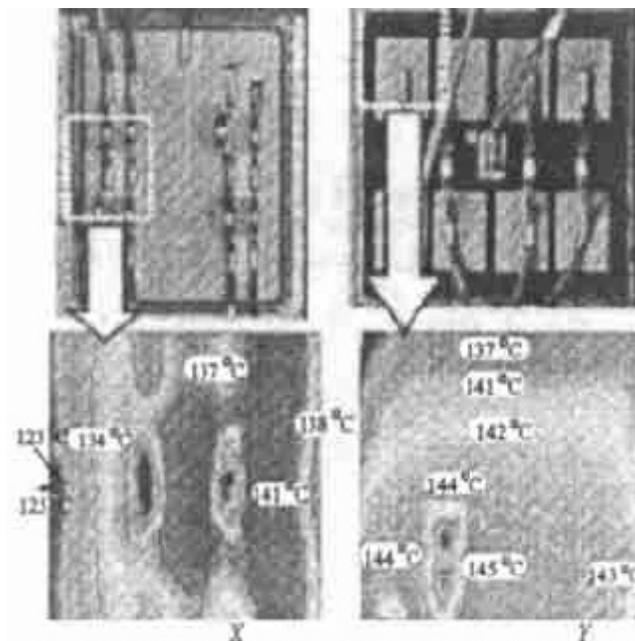


Figure 4 : Temperature field of aluminum wire bonding chips

So current researches mainly focus on chip modules. To analyze chip modules, we should adopt proper plans of integrated circuits and packaging forms, and combine bare chips together to form a module with integrated functions.

Design of the application system of integration module

While designing the application system of integration module, the primary mission is to find the proper module to ensure the stability of the system made by different modules and to optimize the system. But there are no standards of the module, so researches about this field mainly focus on how to build a demonstration system made by modules to improve the credibility and usefulness of power electronic integration. One successful case is integrated AC motor which makes motors to be controllable, smaller and more efficient.

Computer simulation, computer aided design and scheme of power electronic integration module

Electric power devices, circuits, controls, electromagnetism, materials, heat transfer and other areas would use technologies with a high degree of integration, such as IPED and IPED, whose structure and processing techniques are difficult. To overcome the technical challenges of IPED, people would use computer simulation and computer aided design (CAD). But current software cannot process this well, they can only combine different CADs such as circuit, electromagnetism and heat transfer, which is a challenge for simulation and aided design.

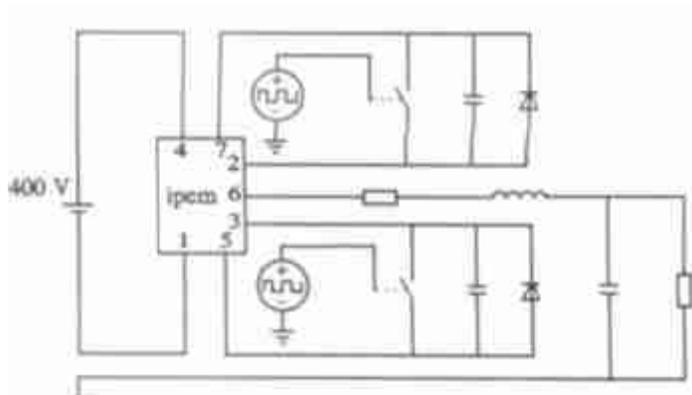


Figure 5 : Circuit simulations



Figure 6 : Heat transfer field

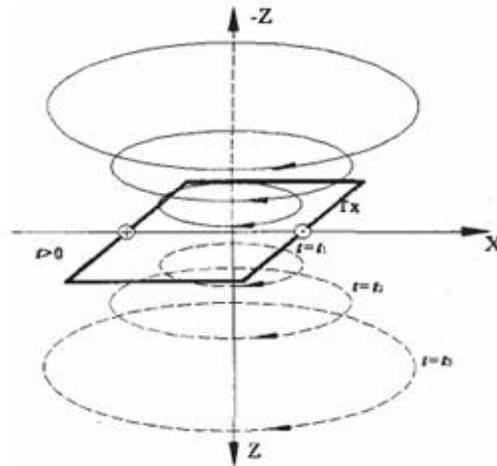


Figure 7 : Whole-space electromagnetic field
DIRECTION FOR THE DEVELOPMENT OF POWER ELECTRONIC SYSTEM
INTEGRATION TECHNOLOGY

With the development of technology, China has progressed in semi-conductor, and monolithic integration is developing towards to have bigger power; hybrid integration has great development prospect in the power electronic integration technology market. Power electronic integration also develops towards being more efficient and minimizing loss and more intelligent.

CONCLUSIONS

Power electronic system integration is the fundamental base of the application of power electronic technology, the intersection of many fields such as industry, information, materials and electrician and the key of power electronic technology in the 21st century. The research about power electronic system integration is very significant in practice. Though the research about power electronic system integration is urgent, however, the research about power electronic system integration is more difficult for integrated circuit with micro-power and large size. China is not mature in terms of digitally assisted power integration and credibility, and we have to devote more people and money to develop power electronic system integration technology. We can contribute to China's power electronic integration if we strive hard.

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