Electric Energy Conversion Technique for Eco-Equipments via Embedded Technology

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Abstract

This paper presents the electric energy conversion systems on a basis of unique embedded systems by the integrated Power Electronics Technology. These play an important role for saving from "the Global warming" in the earth. This paper also gives a learning activities. This teaching materials enables to increase student motivation for their recognizing to all equipment which can be friendly with environment and human society.

These are a key technology in the high performance clean energy for future.

Keywords: The Global warming, Embedded system, Electric energy conversion, Converter, Digital signal processor.

1. Introduction

Regarding "the Global warming", increase of greenhouse gases as a result from human activities such as fossil fuel burning and deforestation to produce etc., lead to higher average temperature of Earth's near-surface air and variety of abnormal behavior. We must realize the new technological innovations that are friendly with environment as soon as possible. One of the final goal for zero pollution society is utilizing electrical energy, for example solar energy, wind power, electric vehicle, hybrid electric vehicle and hybrid electric energy, etc. These should be both higher reliability and compact. The embedded technology gives a solution for above contradicted problem.

This paper presents the electric energy conversion systems on a basis of unique embedded systems by the integrated Power Electronics Technology. These are the most important techniques for Eco-Equipments. This paper also gives a Multi-Purpose Converter as learning activities[1]. This teaching materials enables to increase student motivation for their recognizing to all equipment which can be friendly with environment and human society. The experiences and skills by making the converter play an important part in the future environmental issues. These are a key technology in the high performance clean energy for future.

2. Elements of electric energy conversion technology

2.1 Hardware configuration

Figure 1 shows a high-performance micro-controller "Piccolo" with 32-bit C28-core-CPU 40/60MHz, which has many following features as:
(1) 32-bit arithmetic functions, (2) the power supply is available from a USB port, (3) low power consumption, (4) 150ps re-solution Pulse Width Modulation (PWM), (5) up to 13ch 12-bit A/D converters, (6) including "Control Law Accelerator" and internal analog comparator.

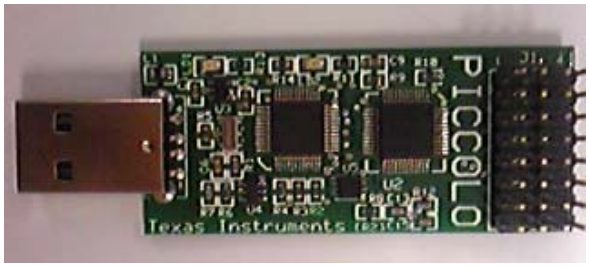

Fig. 1 High-performance micro-controller "PICCOLO"

Figure 2 is the configura-tion of the multi-purpose con-verter developed in our Laboratory, consisting of "Piccolo" as a core processor, the gate drive circuits, main-circuit, and sensor circuits for measuring voltages, currents and the others.

To accommodate many kind of converters, power MOSFETs are connected in series like a totem-pole. Voltage, current and displacement are taken into the "Piccolo" through each sensor. The 1-bit digital input is used as start command and initializes the control system. Converter output voltage is given by PWM signals. If errors such as over-current, over-voltage and/or other dangerous conditions occur, emergency stop signal (EMG) allows to protect not only main circuit but also any devices of the system. In the gate signals of MOSFETs, dead time of 1μs is appended to prevent from dead-short in the upper-side and lower-side MOSFETs. It is important to use

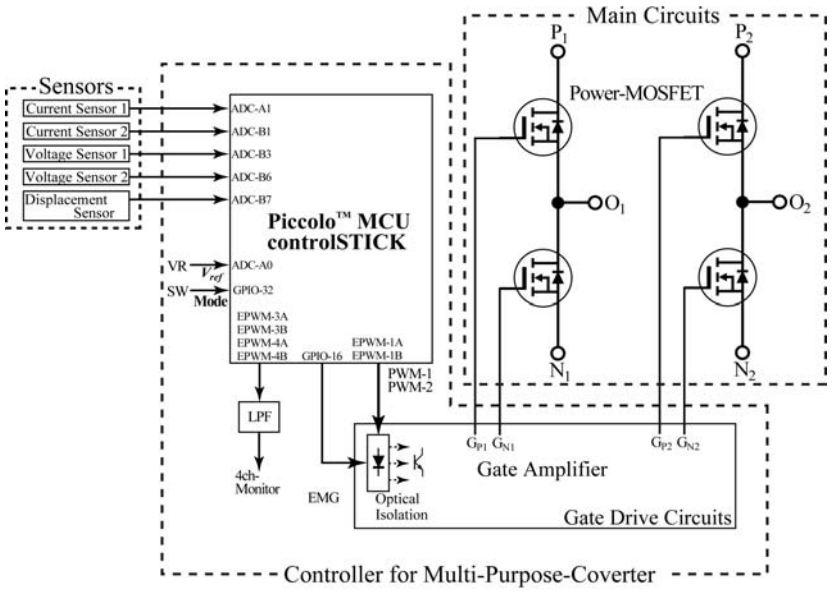

Fig. 2 Circuit diagram of multi-purpose converter for power-electronics equipments

the low pass filters to suppress noises due to switching of power MOSFETs.

Figure 3 shows the multi-purpose converter made by a 4th grader student of bachelor course in our college.

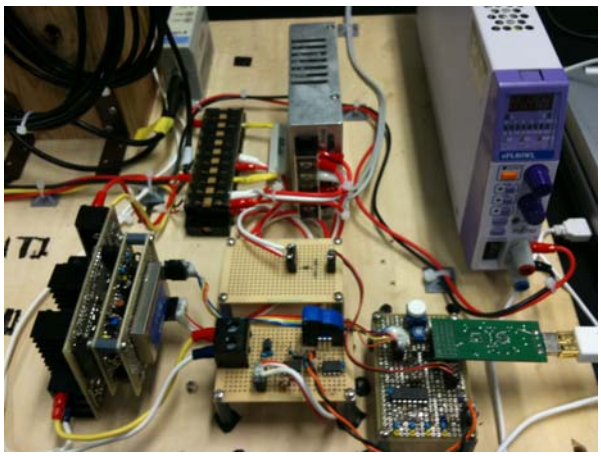

Fig. 3 Multi-purpose converter

Figure 4 shows an example as a single-phase inverter. Terminals P_1 – P_2 and N_1 – N_2 are connected each other, and DC source are

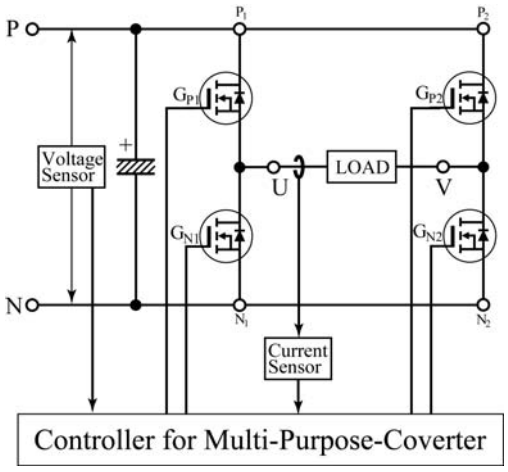

Fig. 4 Example connection as a single-phase inverter

supplied between terminals P and N in Fig. 4. A set of terminals U and V is inverter output which supplies the AC electric power to load.

The proposed multipurpose converter can be adopted to many other applications such as buck, boost, buck-boost DC-DC converters and AC-DC controlled-rectifier, etc.

2.2. Software configuration and development tools

Both high reliability and simplicity are demanded in the electric energy conversion system. Because, it deals with high voltage, large current and high density of energy, so that a little malfunction may cause a serious accident. To trade off the reliability and complexity, we introduce the development tool "Capsule Works" which derived from autonomous capsule theory[2]. This idea of autonomy is a collection of mimic software components like the living cells with encapsulation and a simple common structure.

This is one of the object-oriented programming method, with the following outstanding features: (1) Each program consists of few hundreds of lines of code, and it has one single function with a common structure. (2) Time slot is predetermined to execute the jobs periodically and stably.

2.3 Advanced control apparatus

An optimal control has the following advantages: (1) the gain margin is infinity, (2) the reduction in gain is at least 50%, (3) the phase margin is not less than 60 degree, and it is not sensitive to variation of parameters. However, the procedure for solving the Riccati equation is complex and the relations between solution and

response in the servo-system are not clear[3].

The inverse LQ strategy has the advantages of (1) transfer functions between inputs and outputs can be asymptotically designated for desired specifications, (2) optimal solutions are analytically obtained and their optimality is guaranteed, (3) optimal gains can be easily adjusted to obtain desired responses[3]-[5].

Figure 5 illustrates the typical ILQ servo-system. K_F^0 and K_I^0 are basic optimal gains, and Σ is gain adjusting parameters. Minimizing the quadratic cost function, we can find out the optimal gains analytically as follows:

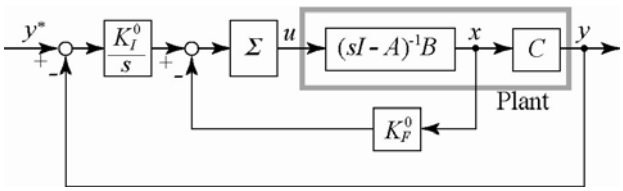

Fig. 5 Robust optimal servo system via inverse LQ control

$$\begin{bmatrix} \boldsymbol{K}_F^0 & \boldsymbol{K}_I^0 \end{bmatrix} = \begin{bmatrix} \boldsymbol{K} & \boldsymbol{I} \end{bmatrix} \boldsymbol{\Gamma}^{-1} \quad (2)$$

where K is decoupling matrix and

$$\boldsymbol{\Gamma} := \begin{bmatrix} \boldsymbol{A} & \boldsymbol{B} \\ \boldsymbol{C} & \boldsymbol{0} \end{bmatrix} \quad (3)$$

In addition, optimal condition is as follows:

$$\left.\begin{aligned} &\text{(i)} \boldsymbol{E} = \boldsymbol{\Sigma} - \boldsymbol{KB} - \left(\boldsymbol{KB}\right)^T > 0 \\ &\text{(ii)} \operatorname{Re}\lambda\left(\boldsymbol{F}\right) = \operatorname{Re}\lambda\left(\boldsymbol{A}_{\boldsymbol{K}} + \boldsymbol{GH}\right) < 0 \\ &\text{(iii)} \left\| \boldsymbol{H}\left(s\boldsymbol{I} - \boldsymbol{F}\right)^{-1}\boldsymbol{G} \right\|_\infty < 1 \end{aligned}\right\} \quad (4)$$

Where A, B, C the coefficient matrices, the function Reλ(.) denotes the real part of the eigenvalue, and the constants are defined as $A_k := A - BK$, $G := A - BE^{-1/2}$, $H := E^{-1/2} K A_k$.

3. An example of application

In this chapter, we introduce an application example of the proposed converter.

Figure 6 and 7 show an Maglev system for student education. Controlling the current of electromagnet by “Piccolo - Inverter”, iron core

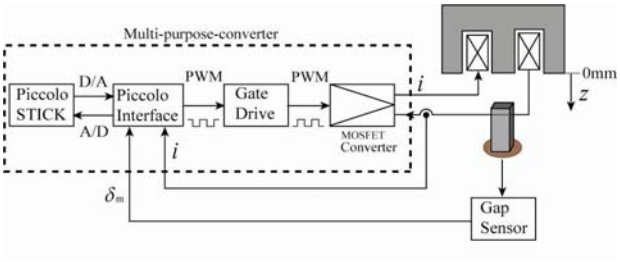

Fig. 6 An application as Maglev system for student education

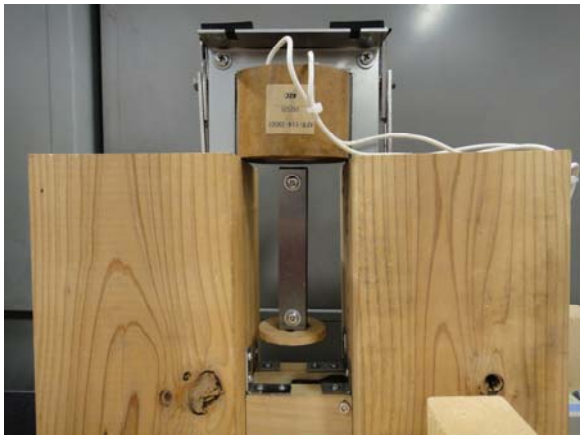

Fig. 7 Experimental situation in proposed Maglev system

levitates stably in the air. By the ILQ control theory, students without sufficient skills can find out easily the optimal gain. Figure 8 shows experimental results of airgap-length and electromagnet current, respectively. The stable levitation control is achieved. We have many other applications by our strategies[6].

4. Conclusion

Excellent Eco-Equipments can be constructed with high-integrated Power Electronics

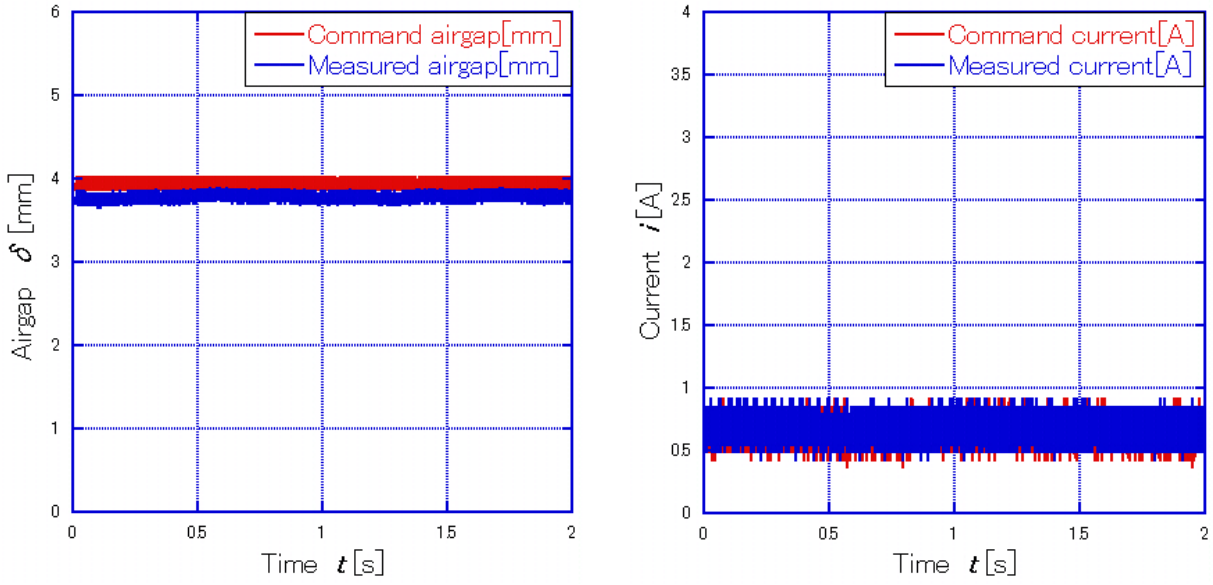

Fig. 8 Experimental results

technology that combines the unique embedded techniques of hardware, software and control theory. Fusion of the high-end technologies leads to the best electric energy system. The Integrated Power Electronics is the important technology, which saves all lives and things on the earth from the global warming.

5. References

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