ISSN: 1813-4890

Design of micro temperature difference power generation system

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Abstract

Temperature difference power generation is a new type of energy that uses temperature difference to generate electricity. The temperature difference power generation system consists of three parts: a temperature sensor to detect the temperature, a storage liquid or liquid mixture which is used as a temperature difference converter to provide the temperature difference and a thermocouple to convert this temperature difference into electrical energy. In this paper, a microcontroller will be utilized to control the storage and release of energy and for the detection of the sensor. This paper focuses on the design and optimization of the miniature temperature difference power generation device to achieve high efficiency and stability of miniature temperature difference energy harvesting.

Keywords

Temperature difference power generation; energy harvesting; energy management.

1. Preface

Temperature difference power generation technology is to utilize the temperature difference to generate electricity. At present, subject to the limitations of the natural environment and equipment, large-scale temperature difference power generation geothermal power generation temperature difference power generation and so on are applied in a small number of fields. And small temperature difference power generation equipment flexibility and other advantages, in the application of special occasions show a greater potential for development. The principle is based on the thermoelectric effect. The electric potential accumulation, for the potential accumulation, this paper will collect the energy processing and storage, the use of microcontroller control of energy storage and release, and for the detection and conversion of the sensor, to improve the output voltage and power, you can use thermocouples in the composition of thermoelectric stacks between different materials and optimize its voltage processing.

2. Temperature difference power generation application scenarios

2.1. Industrial waste heat utilization

Major manufacturing and processing industries produce waste gases and liquids to a greater or lesser extent in the production process, in which case we can utilize waste heat and temperature difference power generation technology to improve energy efficiency. As early as 1984, Japan completed the completion of a temperature difference power generation unit that can work with industrial waste heat. By combining temperature difference power generation equipment with boilers in thermal power stations and analyzing the energy efficiency, it is possible to improve the efficiency of thermal power stations.

2.2. Automotive waste heat utilization

Most vehicles on the market consume petroleum energy, but nearly 60% of the fuel's energy is not fully utilized, and most of it is emitted into the atmosphere as waste heat. Japan's Nissan

ISSN: 1813-4890

company developed a car exhaust gas temperature difference generator, can be generated by the waste heat energy utilization of nearly 10%. Temperature difference power generation technology for automobile emissions waste heat will better utilize the existing resources, to a certain extent, to reduce energy waste and improve the quality of the atmospheric environment[1] .

2.3. Ocean thermal power generation

The ocean area is the vast majority of the Earth's surface area, and the resources it contains are also and its richness, the ocean area is the vast majority of the Earth's surface area. 2007～2008, the First Institute of Oceanography of the State Oceanic Administration (SOA) designed a 250w small-scale experimental device for the utilization of temperature difference power generation[2] . In the follow-up research, China became the country that can realize ocean temperature difference power generation after the United States and Japan. This initiative optimizes regional energy resources and contributes to the early realization of the goals of "carbon neutrality" and "carbon compliance".

2.4. Other applications of differential temperature power generation

Prof. Rowe converted the heat of wastewater after bathing into electricity and applied it to home appliances; a Japanese company utilized the body surface temperature of human beings to convert it into watch batteries through temperature difference power generation technology[3] . Solar Energy Geothermal Energy The success of these studies[4] also indicates that the temperature difference power generation technology and its applications have good development space and market prospects. The corresponding finished product research can play a role in saving resources, and play a certain role in protecting the environment[5] .

2.5. Current status of domestic and foreign research

Domestic research on temperature difference power generation did not start too early[6] , domestic research on temperature difference power generation is mainly to study the theory of temperature difference power generation technology and power generation equipment and material preparation, to provide theoretical guidance and materials for optimizing temperature difference power generation. Chen Jincan's group, in the 1980s, began to study the basic theory of temperature difference power generation equipment, optimize the performance of temperature difference power generator, and get good results. Li Yudong analyzed the working performance of generator under low temperature difference under the perspective of fire use .Jia Lei put forward the point of view of Thomson's heat on power output under low temperature and large temperature difference conditions .Jia Yang . analyzed the physical parameters of the thermoelectric material and their changes on the working characteristics of the generator by numerical calculation, and established a thermoelectric coupling analysis model for temperature difference generator, etc.

Since 1821 Ebeck discovered the Sebeck effect, foreign countries on the temperature difference power generation has been a lot of research, 1947 the first temperature difference generator of the introduction of the efficiency of the synthesis is only 1.5%, used for the space shuttle, the military and ocean exploration, the United States in the early 1980s and completed the development of 500 to 1000 watts of military temperature difference generator, and so the Japanese Armed Forces to carry out the "solid waste combustion energy recovery research program", the solid waste incinerator waste heat power generation technology to achieve the maximum utilization of different scales of waste incineration heat with the exhaustion of fossil energy, the United States and the former Soviet Union to develop radioisotopes or nuclear reactor temperature difference generator, the supply of ocean power, Japan, France, Belgium, etc. have built some seawater temperature difference generators, the United States, France, Belgium, Japan, France, Belgium and other countries have built some seawater temperature

ISSN: 1813-4890

difference generators, the United States of America, the United States of America and the former Soviet Union. Japan, France, Belgium and other countries have built some seawater temperature difference power stations.

3. Energy management system

A small micro-power system is divided into two parts, micro-energy acquisition: this part can be solar energy, or temperature difference power generation energy, or miniature wind power, tidal power, etc., this part of the micro-energy acquisition from the temperature difference power generation; the other part of the micro-power monitoring, energy management system. Here in this paper, the energy management circuit is used to increase the voltage to the available range stored in the capacitor waiting to be used, microcontroller control sensors to briefly use the energy and send and receive data.

The Cockroft-Walton voltage doubling rectifier circuit[7] working principle diagram is shown in Figure 1. When the AC current changes, the use of diodes will be the two currents generated by the charge were stored to their respective capacitors, through the two capacitors placed in a reasonable design, according to the principle of capacitance polarity additive, after several cycles, the capacitor[8] C2 charging the highest voltage value of the AC power supply voltage and the capacitor C1 voltage sum, which can be derived, the load side of the output voltage continues to rise, and ultimately for the AC power supply AC voltage value of twice.

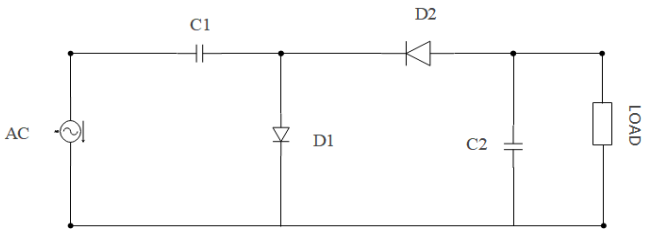

Fig. 1 Cockroft-Walton voltage doubling rectifier circuit

The Cockroft-Walton doubling rectifier circuit has difficulty in achieving the required requirement due to less energy collected and lower voltage. So this design can combine two sets of voltage doubling rectifier circuits with opposite polarity into a quadruple rectifier circuit to achieve the required voltage requirement. The quadruple voltage rectifier circuit is shown in Figure 2. The final output voltage is twice that of the Cockroft-Walton voltage doubling rectifier circuit, i.e., four times the input voltage.

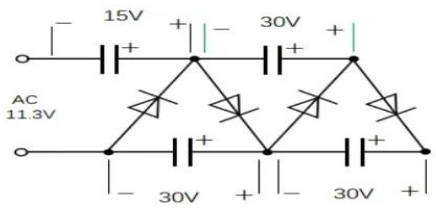

Fig. 2 Quadruple voltage rectifier circuit

4. Sensor monitoring system design

4.1. Sensor system functions

The sensor detects the measured information and transforms it into an analog or digital electrical signal output according to certain laws. In this design, the analog quantity can be converted into available information by using the 10-bit AD acquisition of the MSP430F4152 microcontroller, and the digital quantity can be directly transmitted using the protocol.

ISSN: 1813-4890

Considering the power limitation, this paper adopts the HTU21D temperature and humidity sensor module as an example to verify the feasibility of the micro-energy harvesting system, which consumes a maximum power of only 2.7uW.The HTU21D temperature and humidity sensor module is based on the high-performance humidity sensing element, which has the advantages of fast response speed and strong anti-interference performance, and it outputs a calibrated digital signal through the standard I2C format. The supply voltage range is 1.5V～3.6V, the humidity measurement range is 0~100%RH, and the temperature measurement range is -40℃~105℃, which is suitable to be used as the sensor of this system.

4.2. Sensor System Programming

MSP430F4152 microcontroller as the core processing unit, need to coordinate the sensor system, data transmission and other operations. Through the reasonable design of the program, it is downloaded into the microcontroller, and the flow chart is shown in Figure 3

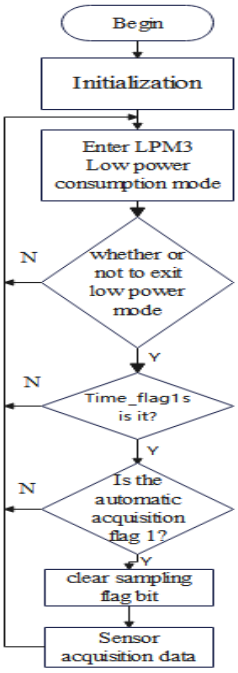

Figure 3 System main program flow chart

5. Summary

At present, in some specific areas, such as aerospace, environmental protection, etc., have been applied to the temperature difference power generation technology. Temperature difference power generation technology is likely to be applied in the future with the development of technology, energy demand, the scope of application will be greater. Temperature difference power generation has the advantages of mature technology, long working life, reliable, etc., large-scale equipment has been widely used for the deep sea and other special environment power supply, automobile waste heat utilization and other special working conditions. Although its power generation efficiency is low at present, the temperature difference power generation equipment is still improving the structure, optimizing the performance, as well as continuously upgrading the power generation device technology. Expecting further breakthroughs in key technologies, the promotion of temperature difference power generation technology can be utilized in more fields. The paper firstly analyzes the application scenario of temperature difference power generation technology, combines the current research situation at home and abroad, manages the energy collected by temperature difference power generation, and analyzes the possibility of improving the utilization of temperature difference power

generation energy collection and energy conversion efficiency. In this paper, we design the microcontroller scheme of the temperature difference power generation energy collection system, choose the HTU21D temperature and humidity sensor module with maximum power consumption of 2.7uW as the sensor system of this design, and introduce the design scheme of the sensor program system to build a framework of the microcontroller sensing system.

Acknowledgements

This work is supported by the research fund of the Quzhou University National College Student Innovation Project 202211488049，202211488057and Quzhou University Innovation Project Q21X001, Q21X011 Q21X012.

References

[1] Zheng Yi-Hua, Ma Y-Z. Temperature difference power generation technology and its application in the field of energy saving[J]. Energy Saving Technology, 2006(3).

[2] ZHAO Jianyun,ZHU Dongsheng,ZHOU Zeguang,et al. Research progress and current status of temperature difference power generation technology[J]. Power Supply Technology,2010(3):310-313.

[3] Lou Suan, Li Yulan, Wang Qian. Research status of micro-scale combustion temperature difference power generation technology[J].2014(6).

[4] HUO Meng, WU Ge, YUAN Hong, YANG Hongfa, XIONG Siyong, ZHANG Zhifeng. A review of research on temperature difference power generation technology[J]. Technology and Innovation, 2095-6835(2020)10-0094-02.

[5] ZHANG Y, WANG H, KTAEMER S, et al. Surfactant-freesynthesis of Bi2Te3-Temicro-nano heterostructure with enhanced thermoelectric figure of merit [J] .

[6] Yin Weihua.Situation analysis of energy industry in 2020 and outlook for 2021[J]. China Price,2021(02):15-17.

[7] He Zenghui, Mao Peng, Zhang Xiaoqiang. Study on the output voltage of distributed capacitor and voltage doubling circuit[J]. Electrical Drives Automation.2022, 44(03)

[8] YU Lili,ZHU Junjie,ZHAO Jingtai. Current status and development trend of supercapacitors[J]. Nature Magazine,2015,37(03):188-196.