

A Self-Powered Energy-Saving Epidemic Prevention Tent

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Abstract: The current situation of the epidemic is complex and changeable. Under the China adherence to the “dynamic zero clearance,” epidemic prevention and control is closely related to all walks of life, and epidemic prevention awning has become one of the essential basic epidemic prevention facilities. However, most of the epidemic awnings are manufactured for the isolation and protection from wind and rain, which could not meet the needs of electricity allocation during emergencies. Therefore, our goal is to design a new energy-saving epidemic prevention tent that is green, stable, and easy to shrink. It is equipped with multiple energy storage and multivariate methods to achieve self-supply of electric energy. First the “1+1” arrangement design of solar power panels on the anti-epidemic tent and pressure power panels combined with the design of pressure power panels under the tent can receive various energy inputs. At the same time, retractable brackets are designed under the four pillars, which are easy to fold and enhance the stability of the canopy. The utilization of energy is more diversified to achieve the purpose of energy conservation and emission reduction. Its market value is broad, and the development prospect is good.

Keywords: Anti-epidemic tent; Self-powered energy system; Energy saving and emission reduction; The new model

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1. Introduction

Since the outbreak of COVID-19 in 2020, epidemic prevention and control has become a vital part of everyone's life. In railway stations, airports, and many places where temperature measurement is required to control the flow of people in and out ^[1], epidemic prevention tents are used with high frequency. Tents that are currently in use are often equipped with infrared temperature measurement and control, disinfection, and other functions ^[2]. In addition, tents in some areas are also equipped with electric fans and other electrical equipment. However, the majority of tents currently in use in China only have the functions of isolation space, and sun, rain, and lighting protection with relatively single functions. Since the electricity energy technology is an emerging and has wide application prospect in energy technology ^[3], the super capacitor between conventional capacitors and rechargeable batteries are the new type of energy storage device with both capacitor fast charging and discharging characteristics, at the same time has a battery energy storage property ^[4], which is very suitable for application in the energy supply system.

2. External structure of the epidemic prevention tent

2.1. The steel parts

The upper part of the pillar structure of the epidemic prevention tent is an umbrella support structure, realizing the function of semi-automatic expansion of the tent. The framework can be expanded and contracted to ensure easy handling of the epidemic cover. All structures have smooth edges, high safety, energy saving, high strength, stable structure, and long service time. The foot support of the epidemic prevention canopy is designed as a retractable support, which presents a triangular structure on the vertical surface after being expanded to enhance the stability of the epidemic prevention canopy. In addition, the brackets can be fully shrunk and folded to facilitate the movement of the epidemic prevention canopy after folding. After the expansion of the two brackets between the feet of 90 degrees, the bottom of the canopy can be further pressed firmly. Compared with the ordinary epidemic prevention awnings with only four pillars, the new epidemic prevention awnings are fixed by sandbagging and other methods when the environment becomes bad. Further, the support structure designed by the new epidemic prevention awnings can ensure the stability of the awnings while realizing the foldable form, easy to carry, and convenient.

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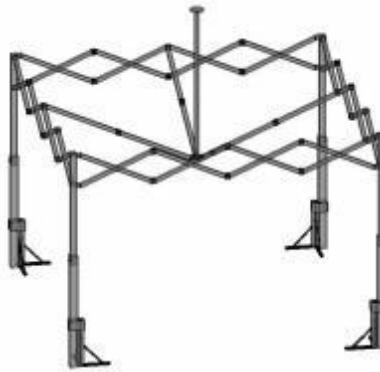


Figure 1. Pillar structure of the new epidemic prevention awning

2.2. The top surface parts

In terms of awning materials, the material for folding awning includes monocrystalline silicon solar panels, pressure power generation board, folding film, and heat insulation layer. Meanwhile, the structure is arranged up and down with upper pressure power generation board and lower solar power generation board. To ensure that the canopy surface will not be damaged in the process of folding and opening for many times, folding film is pressed on both sides of the splicing board in the design. To keep the canopy cool and comfortable, the interior of the canopy is insulated. In addition, the splicing position is designed to have a certain gap to ensure the folding. There are also a few gaps between the upper and lower panels, which are conform to the folding structure. This combination design can meet the needs of realizing the folding function, when expose to energy input in various environmental conditions and weather. A 50*200cm pressure generator board is placed on the side near the door at the bottom of the quarantine cover, which fully considers as a space for human activities, and to collect piezoelectric energy as much as possible while saving piezoelectric materials.

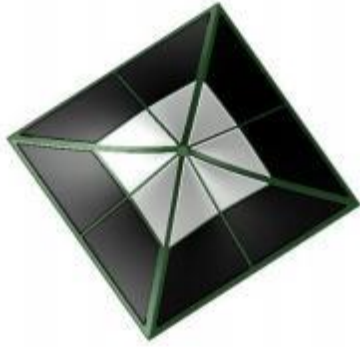


Figure 2. Schematic diagram of solar panel generator board



Figure 3. Schematic diagram of pressure

3. Circuit

The design uses self-powered energy technology, don't need to charge, but only rely on their own energy from outside and timely storage. Supercapacitors usually have high power density and long cycle stability, which are very suitable for application in energy storage components of self-powered energy systems^[5]. On the one hand, high power density is very suitable for bearing large output current, while good cycle stability is suitable for improving the service life of self-powered energy systems. System control adopts STM32F103C8T6 as the master chip with abundant external expansion functions^[6]. Therefore, a set of self-powered energy system with solar panel and pressure generator board as the energy input, super capacitor (specification 8F/5V) as the energy storage element, and STM32 microcontroller as the core of the control circuit is designed.

3.1. Collecting circuit

In this design, the power source stored by the supercapacitor is divided into two parts, which are solar panel power generation and piezoelectric material power generation. Solar panel power generation is dependences on the intensity of sunlight exposure; therefore, the output voltage of the solar panel will fluctuate. It is important to stabilize the voltage to 5V before charging the supercapacitor. The voltage regulator circuit adopts XL6009 automatic voltage rise and fall module, R2, R1, and XL6009 chip internal circuit composed of negative feedback stable output voltage by the resistance R2 and R1 control voltage amplification, and the output voltage (VOUT) calculation formula is $V_{OUT} = 1.25 * (1 + R2/R1)$, in which the efficiency can reach more than 90%.

Figure 4 shows the schematic diagram of the pressure generator board. Pressure plate power generation: Due to the variability of wind and rain in the environment and the randomness of the force in the process of walking, the pressure of piezoelectric ceramics is different, thereby the voltage of the output of piezoelectric ceramics will be unstable, which may produce alternating current. The full-bridge corrector is used to rectify the unstable AC in the transmission circuit of the pressure plate, subsequently the voltage is raised to 5V through the booster module to enter the storage of the supercapacitor component. Boost module adopts SX1308 chip, input wide voltage 2V-24V, working frequency is fixed to 1.2mhz, internal 4A current limit, output voltage up to 28V, and maximum efficiency up to 97%.

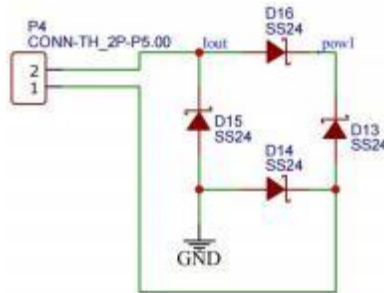


Figure 4. Schematic diagram of pressure generator board

3.2. Discharge circuit

The discharged circuit in this design is mainly the circuit of the supercapacitor. The discharged output voltage of the supercapacitor is 5V, and the input voltage of the STM32 mono-chip computer is selected to 3.3V, thereby it needs to go through a voltage regulator circuit to reduce the voltage from 5V to 3.3V, and input 48 pins of the STM32 mono-chip computer. The voltage regulator circuit uses Low Drop-out Linear Regulator (LDO). VOUT is connected to the reverse and forward ends of the LDO error amplifier through two resistor dividers. Metal-Oxide-Semiconductor Field-Effect Transistor (MOS) drive is used to adjust the output voltage to achieve output stability. When the output voltage increases, the amplifier output voltage increases, the G-pole voltage of the PMOS tube increases with decrease in Undoped Silicate Glass (USG), and the output current and voltage of positive channel Metal-Oxide-Semiconductor (PMOS) is smaller forming a negative feedback system.

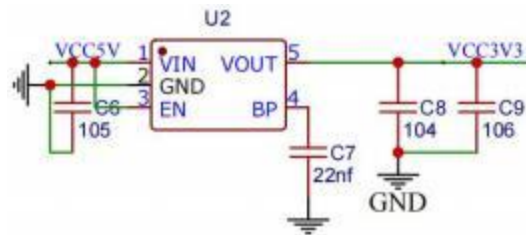


Figure 5. Voltage regulator circuit diagram

3.3. Part of the electrical output circuit

The anti-epidemic tent is connected to each pin of STM32 MCU to achieve different functional control effects. The display control circuit consists of STM32 MCU which has an internal LTDC LCD controller, and using some parts of CDRAM space as video memory which can directly control the LCD panel, therefore another LCD controller chip is not required. **Figure 5** shows the voltage regulator circuit diagram. The STM32's LTDC LCD controller supports up to 800x600 resolution screens that display the time, temperature, and pressure values in real-time.

Lighting device driving circuit: The use of electromagnetic relay on low voltage and weak current control circuit to control high voltage and strong current working circuit, the output circuit of the electromagnetic relay, and lighting device connection. Set pin PC13 of STM32 as the corresponding pin of output mode, connect pin PC13 with the 3.3V voltage output port, and connect to the input loop of the electromagnetic relay as power supply. The level of the pin can be fixed by Supply Chain Management (SCM) program to control the output circuit of the electromagnetic relay, to control the working state of lighting devices. Lighting devices have two modes of operation, key mode, and automatic mode. The key

mode is connected with the key circuit by the switch, and the switch can be used to manually control the connected state. Meanwhile, automatic mode is to achieve intelligent lighting through A/D conversion module, SCM can detect whether the pressure power generation device is generating power, also can detect the resistance value of photosensitive resistance.

4. Energy saving performance calculations

The epidemic prevention canopy that we designed is 300cm long, 300cm wide, 200cm high, and 295cm high. The specifications of single solar panel are 560mm*540mm monocrystalline silicon solar panel with 60W power and 12V output voltage. 24 solar panels are installed on the roof of the epidemic prevention canopy. Taking Wuhan as an example, the average sunshine time in Wuhan is about 1950h a year, thereby the average sunshine time is 5.3h a day. The calculated DC power output of solar panels is the nominal power of solar panels. Solar panels in field operation often fail to meet the standard test conditions, and the allowable deviation of output is 5%. Therefore, the influence coefficient of 0.9 to 5% should be taken into account when analyzing the output power of solar panels. The photovoltaic panels on the top of an epidemic prevention canopy generate 2.014kWh of electricity per day.

At the bottom of the roof, a pressure generator plate of 50*200cm size is used, with a single specification of 50*50mm. Considering that there should be a certain gap between the pressure generator plates in parallel, and according to the human foot type and the force distribution characteristics when contacting the ground, the piezoelectric plates are arranged, a total of 345 pieces is calculated. In the range of elastic deformation, the weight of a human is 60kg, the acceleration of human foot is 10m/s², the piezoelectric constant is $D = 1010 \times 10^{-12}$, the relative dielectric constant is $\epsilon = 4450$, the density is $\rho = 7.39 \times 10^3 \text{kg/m}^3$ are calculated based on a stepping piece of piezoelectric ceramic which can generate 0.175MW electric energy. At the bottom of the canopy, 345 piezoelectric ceramic pieces are installed, which can generate 60.4MW electric energy at a time. Taking the comprehensive nucleic acid test of a university as an example, 25 epidemic prevention awnings were set up for more than 25,000 people in a university, and all of them were required to complete the test within 6 hours. One person took about 7 steps in and out of the epidemic prevention awning, and each step was covered with 3 pressure generating boards on average. Therefore, the energy generated under an epidemic prevention awning in a nucleic acid test was 1.205kWh.

The roof is equipped with a pressure generator board which can input energy irregularly from environmental wind and rain. The diameter of a raindrop ranges from 1 to 6mm. According to the raindrop spectrum, the total density of raindrops is 3000-10000/m³, the rain time is 5 hours, the rainfall intensity is 0.97-1.95mm/min, and the wind speed is 8.0-10.7A. A quarantine canopy can provide 0.415kWh of electricity per day. In the context of epidemic prevention and control, a new epidemic prevention awning can generate 3.219kWh of power on sunny days, and the solar power panel can generate 2.023kWh of power on rainy days, in which only about 20% is generated on sunny days. Taking Wuhan Institute of Technology Liufang Campus as an example, the campus has nearly 30 epidemic prevention tents, including 7 temperature tents that need electricity and work for 24h a day. The temperature measuring tent is equipped with an electric fan to ensure the air flow in the tent, and a light and a screen to display the temperature of the students. The temperature tent is equipped with Oppl Lighting Co., Ltd.'s energy-saving lamp with power usage about 18W. It is usually turned on at 18:00 in the evening and turned off at 6:00 the next day. It works for about 12h a day. The electric fan fixed in the temperature measuring tent is a circulating fan with a power of 31W with low noise. The electric fan is turned on in hot weather (used all day), and the use time accounts for about one quarter of the whole year, namely 3 months. The established temperature measuring instrument is used all day and the power is about 20W. In a year, the temperature measuring tent in school includes three months with fans usage and nine months without fans usage. When fans are used,

the average power consumption of a day is 1.44kWh, while when the fan is not used, the average power consumption of a day is 0.696kWh, and the effect of self-supply can be achieved in all weather conditions. An epidemic prevention tent consumes about 322.488kWh of electricity in a year. At present, China consumes about 0.34kg of coal for one hour of electricity generated, and 0.87kg of carbon dioxide is generated based on 70% carbon content of coal. By using the new epidemic prevention tent, we can reduce coal consumption to 767.52kg per year, subsequently reduce 1.96tons of carbon dioxide emissions. The effect of energy saving and emission reduction is obvious.

5. Working principle and performance analysis

The anti-epidemic tent consists of a steel frame canopy, a compressible pillar structure, and an anti-epidemic covered with solar and pressure panels. The design of power planning and circuit control to STM32 microcontroller are the core, supercapacitor as the storage element with the corresponding functional modules to achieve.

On sunny days, when the sun shines on the anti-epidemic tent, the solar energy is converted into electric energy and stored in the supercapacitor through photovoltaic power generation panels, and the output electricity is applied to various functions in the shed. In windy and rainy weather, the power of wind and water is converted into electric energy by the pressure generator board and stored in the supercapacitor or provide electric energy for various activities in the canopy. When entering or leaving the anti-epidemic tent, people step on the pressure of the power plate, piezoelectric material connected to the circuit and disinfection equipment which supplies the power that they need.

Various details of the design allow users to operate with a high degree of convenience and comfort. When the voltage is detected in the pressure generation device and the photoresistor resistance value is smaller, meaning that the light is dim and someone is passing through. At this time, the MCU controls the output loop of the electromagnetic relay to make the lighting device work. The above mentioned two kinds of electrical function control circuits applied in the new epidemic prevention canopy can well collect and store energy and output it for people's convenience, to achieve the effect of energy saving, emission reduction, and green environmental protection.

6. Conclusion

To a certain extent, this design solves the problems of poor stability, incomplete power supply function, difficult to cope with harsh environment power supply, and single function. The pillar structure ensures the simple handling of the epidemic prevention canopy, and also ensures the stability and safety of the epidemic prevention canopy.

At the same time, power supply can provide the epidemic prevention canopy more functions, improve the utilization rate, and environmental protection of the epidemic prevention canopy. In addition, this design combines small supercapacitors and multi-functional tents with high efficiency of photovoltaic and piezoelectric materials, and at the same time, a set of self-supplied energy system is designed. In response to the current situation of epidemic prevention and control across the country, the concept of combining small supercapacitors, photovoltaic, and piezoelectric materials has been creatively adopted, and a variety of energy storage and conversion methods have been used to save energy and to reduce corresponding pollution emissions.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Ouyang K, Wang Y, 2022, Study on the Precision Prevention and Control System of Covid-19 under the Background of the Mutation Transmission of Covid- 19 Virus. *Journal of Decision and Information*, 2022(04): 5–12.
- [2] Shi C, Ding Y, Yu Y, et al., 2021, Application Status of Mobile Medical Platform in COVID-19 Epidemic Prevention and Control. *Medical and Health Equipment*, 42(11): 63–67.
- [3] Xie G, Wang S, Xie F, et al., 2018, Research Progress of Self-Powered Gas Sensor. *Journal of University of Electronic Science and Technology of China*, 47(1): 139–146.
- [4] Chen Y, Chen Z, 2020, Preparation of Activated Carbon, Graphene and Non-Isoelectrode Capacitive Stream Supercapacitors from New Carbon Sources. *Journal of Physics and Chemistry*, 36(2): 53–71.
- [5] Tian Z, Shao Y, Sun J, 2019, Farewell Charger: A Portable Energy Source. *Chinese Science Bulletin*, 64(36): 3771–3772.
- [6] Tian X, 2016, Design of Intelligent Cooling Rechargeable Solar Umbrella. *Science and Technology Horizon*, 2016(15): 275–276.

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