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**Research Article**

# Research on the Application of the Super Capacitor in the Solar LED Pest Control Light

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**Abstract:** Based on the energy storage characteristics of the super-capacitor and solar panels, this study selects the super-capacitor as the storage device to design the solar LED pest control light, which is energy saving, environmentally friendly, safe and reliable. The solar LED pest control light is easy to use and there is no need erecting and maintaining wires. However, the current storage battery is weak in charge control due to the instability of the sun light and this unstable charge state may lead to its premature failure or capacity loss, thus causing the service life of pest control light to be below the designed specification.

**Keywords:** LED, solar panels, storage devices, super capacitor

## INTRODUCTION

LED pest control light is a physical insecticidal tool and the lights emitted by it could trap and kill the pests in the farmland, thus reducing the pesticide use as well as the pollution of agricultural soil and water and saving the cost of farmers (Zhao, 2012; Zhang, 2011; Liu *et al*., 2011a). The solar LED pest control lights are easy to use and applicable for various crops. Besides, there is no need setting up wires, so the electric shock hazard could be avoided, coupled with the reduction of the workload used for wires maintenance. It is particularly suitable for the remote areas without electricity, such as the tea plantation, orchards, vegetable field, cotton field etc. The solar pest control light converts the solar energy into electrical energy during the day and the electrical energy is stored in the storage system (An and Wu, 2010; Du and Xiong, 2010; Liu *et al*., 2011b; Huang *et al*., 2009; Wang *et al*., 2011). Then the automatic control unit could automatically turn on LED lights and high-voltage grid according to the brightness of the light to achieve pest control. As the pest control light always works at night and the output power of solar panel is apt to be affected by the light intensity, ambient temperature and load fluctuations and other factors, the solar LED pest control light should be equipped with the storage system in order to ensure reliability of load supply and power quality. Therefore, the storage system is a key part of the solar LED pest control light.

Currently, the storage devices mainly include the lead-acid battery, Ni-Cd battery or Ni-H battery, however, there are some shortcomings using storage battery such as the limited charge cycles (<1000) and shorter life; affected by its chemical structure, it is impossible to conduct the large-current charging; the story battery is required to be equipped with the complex control circuits with anti-overcharge, over-discharge property and the temperature compensation; the rechargeable batteries mainly utilize the chemical reactions to conduct charge and discharge and the waste in the battery may pollute the environment. Moreover, the instability of sunlight has increased the difficulty of the charge control and made the storage batteries in an unstable charge status, thus leading to the premature failure or battery capacity damage. Therefore, the service life of the pest control light fails to be up to the design specifications. The super capacitor is an electrical energy storage device, also known as electrochemical capacitor. It has high discharge power of the static capacitor, as well as the long cycle life, high power density, fast charge and discharge, heat resistance, flexible capacity configuration, pollution-free and maintenance-free etc. Therefore, based on the energy storage characteristics of the super-capacitor and the features of solar panels, this study selects the super-capacitor as the storage device to design the solar LED pest control light.

Based on the energy storage characteristics of the super-capacitor and solar panels, this study selects the super-capacitor as the storage device to design the solar LED pest control light, which is energy saving, environmentally friendly, safe and reliable. The solar LED pest control light is easy to use and there is no need erecting and maintaining wires. However, the current storage battery is weak in charge control due to the instability of the sun light and this unstable charge state may lead to its premature failure or capacity loss, thus causing the service life of pest control light to be below the designed specification.

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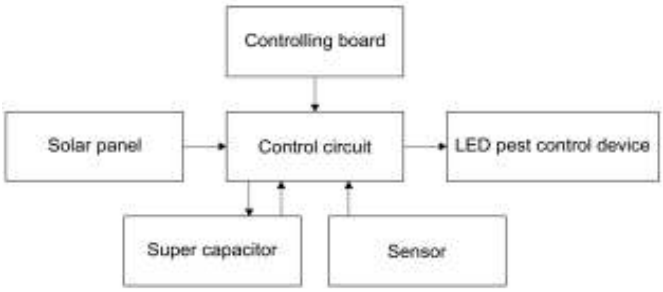


Fig. 1: The schematic diagram of solar LED pest control light

## METHODOLOGY

**The system structure:** This system is mainly constituted by solar panels, super capacitors, control circuit, control keyboard, LED pest control light and sensors, as shown in Fig. 1. The function of solar panels is to convert the solar radiant energy to the electrical energy which is then stored by the super capacitor for the load use; the control circuit is the core of the solar LED pest control system, for the charge and discharge control will directly affect the system's application results, so the charge and discharge controller should have various functions such as the charge and discharge, the maximum power tracking, overcharge protection, over-discharge protection, short circuit protection etc. and automatic switching and time adjustment function. The control circuit could also control the LED pest control light, for the light could automatically turn on at night and turn off during the day. In addition, some safety control functions are also necessary, including the lightning protection, short-circuit-proof of the high-voltage insecticidal nets caused by the rain and dew, accidentally injure resistance of humans and animals, electric shock caused by the leakage of the pest control light, etc.

**Design of the solar led pest control light:**

**LED pest control light:** The tea lesser leafhopper is the dominant population in the pests of the tea plantation, so it has endangered the tea plantation, for its high occurrence rate and density has a great influenced on the yield and quality of tea. The yield loss is up to 15 to 20%, or even 30 to 50%, so there is a serious decline in the quality of tea. The solar LED pest control light in this study adopts the green LED (with the wavelength of 525 nm), blue LED (with the wavelength of 462.5 nm), yellow LED (with the wavelength of 580 nm) as the light source and these three kinds of the light rays are superposed to trap the tea lesser leafhopper using its chemotaxis and phototaxis. The power of LED pest control light source (including the driver circuit) is 9 W and its working voltage is 12 V.

The high-voltage circuit is used to constitute the pulse oscillation circuit by the NE555 and some other devices. Then the high-frequency pulse signal is output to drive the high-power MOSFET, thus inducing the high-voltage pulse at the secondary side of the transformer. Then the high-voltage pulse will be input by the rectifier diode and obtain the 2000 V voltage which is then applied to the power network of the horizontal network structure. At night, the light is automatically turned on to trap the tea lesser leafhopper by the light source, for the tea lesser leafhopper may contact with the high-voltage grid in the periphery of the light when it is flying towards the light source and then be killed by the instantaneous discharge of the high-voltage circuit. The power of the high-voltage circuit consists of two parts: one is the substantially constant standby power; the other is the killing power. Due to the various types and number of pests, it is difficult to measure the killing power accurately; therefore, in the actual application, it is calculated by the average power of the high voltage circuit and its average power ≈6 W and the working voltage is 12 V. The power of the LED pest control light 15W = 9W + 6 W and its working current is 1.25 A.

**Solar panels:** To design the energy configuration of the solar LED pest control light, the on-site daily sunshine duration is the main factor that should be taken into consideration, as well as the machine power for the pest control, namely, the allowable number of discharge hours of the super capacitor when the power generation is not relying on the solar panels. Only when these parameters are clearly defined, can the capacity of the super-capacitor and solar panels parameters be reasonably calculated. There are two peaks for the occurrence of the tea leafhopper throughout the year: the first one is from late May to mid-June and the second one is from October to early November. The solar radiation in Zunyi City is greater in summer and less in winter and the annual average sunshine hours are fewer. The average annual sunshine hours in the past 30 years are 1050.4 h, which is a city with poor sunshine hours in the country. The average annual sunshine hours in the past 30 years are: 90.00 h in April, 102.5 h in May, 103.3 h in June, 171.2 h in July, 182.3 h in August, 113.6 h in September and 77.8 h in October. The insect activities are for feeding and mating, so their intense

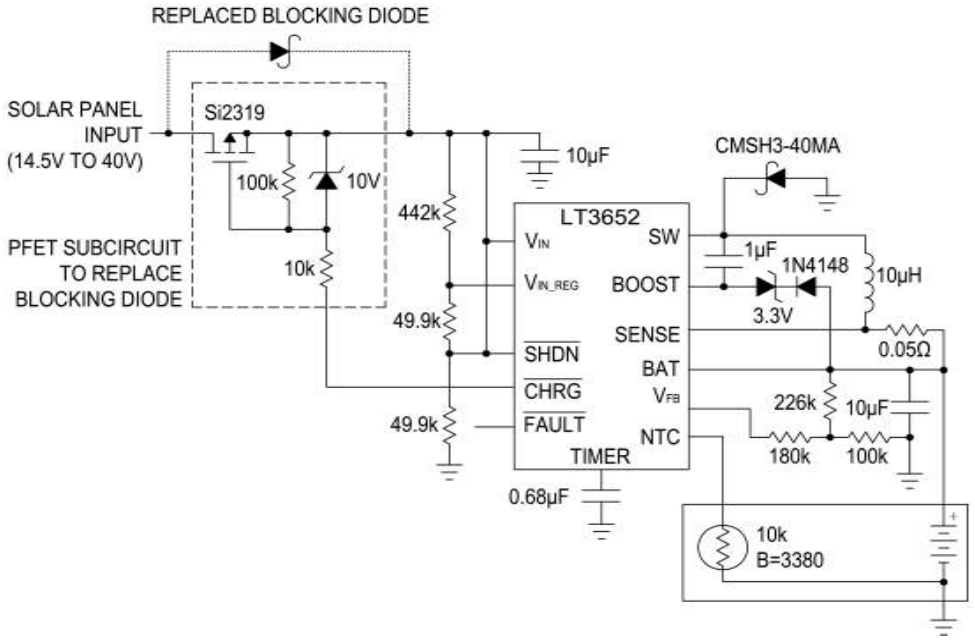


Fig. 2: The schematic diagram of charging regulator circuit

movement makes the evening as the best time to trap them. Therefore, the LED pest control light is required to work for 3 h in the evening.

Based on the above factors, the minimum solar panels are determined --- the polycrystalline silicon solar panel with the output power of 25W±3%, the output current of 1.39 A, the short-circuit current of 1.64 A, the open circuit voltage of 22 V, the output voltage of 18 V and the size of 410×410×30 mm. As the dip of the solar panel in this system is fixed, to make the solar panel emit more energy, the most basic approach is to make the solar panel angle face the south direction with the inclination equal to the local latitude.

**Super capacitor:** Super capacitor is called electrochemical double-layer capacitor, which is a kind of electronic component that can store energy. It is similar to traditional capacitor in terms of work manner and performance and the main difference is that the super capacitor has enormous capacity compared to the traditional one. As super capacitor applies the charge separation technique to store energy, the whole process of the charging and discharging of the super capacitor is always a physical process, which means there is no chemical reaction in energy storage and release. Therefore, the super capacitor is regarded as an ideal energy storage element, which can quickly receive and release energy with very small loss. In order to form a super capacitor module in place of 12 V battery, use twelve 2400F/2.7V capacitors to compose the module, which is made up by four super capacitor cells in series and three units in parallel.

**The charging regulator circuit:** LT3652 is chosen as the charging management chip and the chip uses special input voltage to regulate the loop. The float voltage $V_{BAT}$ = 10.8V, as shown in Fig. 2. XX is the charging management chip for the medium power, using the average current mode buck topology. While the solar panel is used as the input power, LT3652 chip will automatically reduce the charge current to make solar panels keep the output state at the maximum peak power when the solar panel output voltage is reduced to a preset value. The regulation loop of LT3652's input voltage can automatically track the output operating point of the maximum power of solar panels, maximizing their use efficiency. LT3652 chip can set the maximum charging current ≤2A, the input voltage 4.95V~32V and the float voltage $V_{BAT}$≤14.4V (set by the resistor divider). LT3652 works at a fixed 1 MHz switching frequency, with the constant current/constant voltage charging characteristics.

**The voltage regulation output circuit:** The LED pest control lamp works at 12 V, while the working voltage of the super capacitor is 10.8 V and the voltage across it will continue to decrease with the continuous discharging of the super capacitor. When the super capacitor releases 50% of the energy storage, the voltage will drop to 70% of its initial voltage, lower than 12 V operating voltage of the LED pest control lamps, causing the failure of LED lights. Therefore, it requires a corresponding boost control circuit to avoid the impact of reducing the super-capacitor array voltage to the normal operation of the load and to improve the utilization efficiency of super capacitor energy storage.

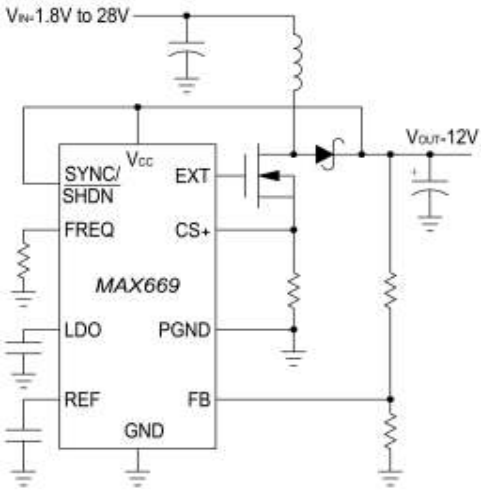


Fig. 3: The schematic diagram of regulated output circuit

The step-up DC-DC chip MAX669 is selected. MAX669 is the PWM controller with a fixed frequency and working in the current mode and its power can exceed 20 W and is adjustable, with the efficiency up to 90%. The input voltage in wide range is 1.8~28 V, allowing it to accept a variety of power input and it is with adjustable frequency range of 100~500 kHz and the ability of externally synchronized operation, etc., making its size and cost optimization for an external component more convenient, which can achieve the isolation of sensitive and switching frequency harmonics. MAX668 is able to drive various types of N-channel MOS-FET and the selected model is FDS6680. As the chip operates at high frequencies above 100 kHz, the diode should select Schottky diode which can shutdown in high-speed. The selected model is MBRS340T3, with the circuit input voltage 1.8~12 V. Super capacitor replacement module has a capacity of 15 A • h, with the output voltage of 12 V and the maximum output current of 2 A. When fully charged, it can meet 12 h electricity demand of LED pest control lamps. Figure 3 shows the schematic diagram of regulated output circuit.

**Control circuit:** The core device of the control circuit is the microcontroller and the charging and supply management of solar LED pest control lights are done by it. In the process of charging, the microcontroller detects the state of the battery and then discharges according to the status of super capacitor. During discharging, the microcontroller will immediately halt to power the load when it detects that the power of the super capacitor is low, which servers to protect the super-capacitor. The microcontroller detects day and night through the photoelectric sensor. During the day, it calls the charging management module to charge the super capacitor and if it is night, then it will call the super capacitor and the power management circuitry to supply the load. Besides, it detects humidity through the humidity sensor to prevent short circuit of high insecticidal net caused by rain and dew.

## CONCLUSION

Combined with the local weather conditions of Zunyi, as well as the photo taxis and activity patterns of the tea leafhopper, an independent solar LED pest control light system based on the super capacitor energy storage module is designed. This system has made full use of the characteristics of solar panels, LED and super capacitor, coupled with the new technology of charge control and discharge management, thereby its simple structure and circuit make it reliable, environmentally friendly and suitable to be used in remote areas without electricity such as the tea plantation, orchards, vegetable field, cotton field and so on.

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