Environment-friendly drying device based on distributed photovoltaic energy

Shihao Zhong¹, Yixin Liu*, Ziqi Tian¹,

¹School of Electrical and Control Engineering, North China University of Technology, Beijing, 100043, China

*Corresponding author’s e-mail:lyx18811706260@163.com

Abstract. In order to achieve sustainable development, reduce the consumption of disposable energy, and meet people's increasing demand for energy-saving living equipment, an environmentally friendly drying device based on distributed photovoltaic energy is designed for drying and sterilizing daily supplies. The environment-friendly drying device drying device uses clean energy, no pollution, intelligent, efficient, low noise, and takes less than 1/4 of the traditional drying equipment. The environment-friendly drying device uses distributed photovoltaic energy to generate electricity, and the electrical energy is stored in the battery when the system is not in operation. The control system adjusts the working state of the heating and cooling systems in time to ensure the stability of the temperature during operation by using a fuzzy adaptive PID algorithm based on incomplete differentiation. Based on the Coanda effect, we independently designed a mechanical structure that doubles the air, enhances the wind mobility, and realizes air circulation and recirculation. The inner wall of the device is equipped with a sterilization device and uses ozone sterilization technology to strictly control the ozone concentration. At the same time, in order to better fit various sizes of clothing, we also design an intelligent control panel that can set personalized drying temperature and time.

1. Introduction
This paper designs an environmentally-friendly drying device based on distributed photovoltaic energy. The power generation system uses clean and renewable solar energy to fully realize self-sufficiency of electricity in the drying device. The fuzzy adaptive PID control algorithm based on incomplete differentiation ensures stable temperature in the device. It is suitable and saves drying time; the air multiplication principle is used to realize the recycling of wind energy and save resources; intelligent design is to carry out corresponding drying treatment for different drying objects, so as to realize the reasonable allocation of resources; built-in sterilization device is to achieve the sterilization effect by strictly limiting the ozone concentration.

2. System design
The environment-friendly drying device drying device is composed of a power supply system, a storage battery and a power distribution system. The system distribution diagram and device assembly model are shown in Figures 1 and 2.
2.1 Power supply system
The power supply system consists of solar panels and batteries. Distributed photovoltaic monocrystalline silicon solar panels are used to convert light energy into electricity through the photoelectric effect\(^1\). The sun shines on the semiconductor PN junction to form a new electron pair, called a hole. Under the action of the PN junction electric field, holes and electrons are moved. The holes flow from the N region to the P region, and the electrons flow from the P region to the N region. After the circuit is connected, a current is formed. The working principle is shown in Figure 3. The solar panel converts light energy into electrical energy, which is converted to 12V by the Buck converter circuit for use by the control system and the power system. Select lead-acid battery for energy storage. When the weather conditions are suitable for power generation, the energy storage battery stores excess electrical energy; when the environment is harsh, the energy storage battery is used as a backup power source to supply power to the control system and the power system\(^2\).
2.2 Temperature and humidity control system

The temperature and humidity control system collects real-time temperature and humidity values through the digital temperature and humidity sensor AM2302, and monitors and adjusts the working status of the heating system and the cooling system of the drying device.

The temperature control system consists of a temperature sensor, a real-time temperature display device, and a PID constant temperature control module [6]. The temperature acquisition circuit uses electrical signals to transmit the on-site temperature to the STM32 single-chip microcomputer. Based on the difference between the current temperature and the target temperature, the single-chip microcomputer calculates the real-time control amount according to the PID control algorithm. The temperature gradually stabilizes at the target value [3].

The humidity control system consists of a centralized dehumidification unit and a humidity sensor. Humidity sensor is used to monitor the humidity in the device in real time. In the air multiplying system, the humidity in the device is reduced by using dry air replacement method to meet the general requirements for humidity and reduce the delay of humidity control. The problem of water vapor returning to the material after the system temperature decreases during the flow dehumidification and co-movement.

2.3 Speed control system

The speed control system consists of a blower and an air multiplication system.

The blast device adopts a fuzzy adaptive PID algorithm controller based on incomplete differentiation. The principle of PID control is shown in Fig. 4. It emulates the use of an actual differentiator with inertia link that cannot be achieved by pure differentiation in an analog control system. The overshoot is small and can eliminate certain noise interference. The incomplete differential PID algorithm transfer function is [1]:

\[
U(s) = \left( K_p + \frac{K_p}{T_i s} + \frac{K_p K_d s}{1 + T_d s} \right) E(s) = U_p(s) + U_i(s) + U_d(s)
\]

\[
(1)
\]
The comparison results of traditional PID, PID-free control curve, and improved algorithm controller algorithm are shown in Fig. 5. It can be clearly seen that the overshoot of the improved algorithm controller is reduced and the rise time is shortened. For the actual speed control process, the improved fuzzy adaptive PID based on incomplete differentiation can ensure the smooth speed of the fan and achieve the purpose of accurate speed regulation\cite{4}.

The Coanda effect refers to the phenomenon that there is surface friction between the fluid and the surface of the flowing object, causing the fluid to change its original direction and flow along the surface of the object. The schematic diagram is shown in Figure 6 (a). The built-in miniature fan makes the air flow out at high speed after reaching the air outlet of the circular fan frame. The gas flowing at high speed changes due to the Coanda effect, which drives the surrounding air to flow forward. When the air flow is discharged forward, negative pressure is generated at the rear, and the rear air also flows forward under the negative pressure, thereby increasing the air flow. According to the working principle of the Coanda effect, the air-doubling system is applied to environmentally-friendly drying equipment, which improves the drying efficiency\cite{5}. The physical model is shown in Figure 6 (b).
Figure 6 Schematic diagram of the Coanda effect

The air multiplication system consists of a miniature fan and an external circulation device. The application principle is shown in Figure 7. The micro-fans on the front and rear of the device can significantly increase the flow at the air inlet, and its flow doubling performance benefits from the air doubling system. The inner wall of the device has micro air holes. The specific distribution is shown in Figure 7. After the dry air is blown into the device to complete the air flow, it is led out from the long slits on the side wall. During the external circulation process, the air is used to dehumidify the air. After the dehumidification is completed, the guiding gas enters again from the lower vent to realize recycling.

Figure 7 Air multiplier schematic and model diagram

3. Drying device model

As shown in FIG. 11, a metal material is used, and the inner and outer double layers are designed. The outer layer size is 400 * 320 * 330mm, and the inner layer size is 320 * 280 * 300mm. The upper cover is connected to the device by a slideway. The front of the device is equipped with a switch button. When pressed, the mechanical control system is activated and the upper cover can be slowly raised and lowered automatically. There are four micro fans on the left and right side walls of the inner layer of the device, which are distributed according to 2 * 2. Heating resistor wires are fixed on the micro fan net cover of the inner layer. A 5g ozone generator and an air dryer are placed between the inner and outer layers. The sterilization and disinfection are carried out simultaneously during the drying process. The DC 12V power supply and the STM32 single-chip microcomputer regularly disinfect the time to ensure that the ozone concentration in the device is lower than the international standard. The side sectional view of the drying device is shown in Figure. The middle part of the inner side wall has 3 parallel vertical slits with a width of 5mm, and the spacing is 10mm. It is
used by the air multiplication system to guide the air flow, which increases by 10-15 times. Air volume, increase air speed, and improve drying efficiency.

![Drying device assembly and side sectional view](image)

4. Future outlook
1) Environmentally friendly drying equipment can basically achieve self-sufficiency in terms of electricity consumption, reduce dependence on large power grids, and extensive use can effectively reduce pollution caused by traditional power generation methods, achieve energy conservation and emissions reduction, and achieve sustainable development[6].

2) The Environment-friendly drying device replaces the traditional natural drying, cooking and disinfection methods, and realizes the integration of drying and disinfection by a fast, efficient and intelligent control method, reducing the loss of manpower, material resources and time.

3) The design of Environment-friendly drying device is very intelligent and humane. While improving the comprehensive utilization of resources, it also meets the fast-paced living needs of today's society. In the future drying device market, it is hoped that it can gradually replace traditional drying devices and gradually enter into children's hospital, family and other application scenarios.

References
[1] Bo,L, Huiling,Q,Yan,W, Xianhong,B.Research on Optimal Design of Wind-solar Hybrid Power Generation Grid-connected System [J].Electronic Design Engineering, 2019,27 (24): 70-74.
[2] Tian,C. Research on Capacity Optimized Allocation of Wind-solar Hybrid Power Generation System and Photovoltaic Maximum Power Tracking [D].South China University of Technology, 2017.
[3] Wei,W, Lei,Z, Pengda,S. Design of Portable Air Purifier Based on STM32 Microcontroller [J].Electronic Manufacturing, 2018 (22): 3-4 + 10.
[4] Zhonggang,X, Xiaoyong,L, Juan,H, Jiang,Z, Ning,X, Qing,L. Design of Speed Optimized Control System Based on Incomplete Differential Fuzzy Adaptive PID Algorithm [J].Journal of Southwest University (Natural Science Edition), 2018,40 (12): 173-178.
[5] Fei,Z. Design and research of leafless fan and its built-in miniature fan [D].Zhejiang University, 2014.
[6] Xuedong,H, Haihua,W, Jianfeng,L. Design of small distributed photovoltaic power generation system [J].Electric Power Construction, 2014, 35 (1): 104-108.