International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 12, Issue 10 [October. 2023] PP: 17-22

Design of agricultural high voltage adjustable switching powersupply based on PID

Sujun CHENG [1] , Shan Li [1,2] ,Pingchuan ZHANG*[2]
School of Physics and Electronic Engineering, Xinxiang University，XINXINANG CHINA School of Computer Science, Henan University of Science and Technology, XINXINANG

ABSTRACT: *For the needs of agricultural physical control of crop pests, design implements a high voltage adjustable wide range of switching power, using ARM 7 microprocessor as power supply controller to complete ADC transformation and running PID algorithm, pulse coding modulation PWM control of adjustment tube, using color TV high voltage package as high voltage pulse transformer. After MATLAB / SIMULINK simulation, the feasibility of the circuit scheme is verified. After testing, it is shown that the output voltage can be continuously adjustable in the range of 1 000 V~20 kV, the load current is 0 ~ 5 mA, and has the characteristics of low size, low cost, wide range and intelligence, which can meet the needs of vegetable leaf pests, and can also be applied to the field of similar indicators.*

Date of Submission: 22-09-2023 Date of acceptance: 05-10-2023

I. INTRODUCTION

Power supply is an important equipment used in physical agriculture for sterilization, pest control, prevention and control of crop pests. At present, there are two main categories of power supply, linear power supply and switching power supply [1]. Switching power supply (Switch Power Supply) refers to the [2-4] used for the voltage regulator in the saturation zone and off zone, namely the switch state. Switch power has high working frequency, the volume of the pulse transformer can do smaller, light weight, simple structure, low cost, high efficiency (efficiency can reach 90%), in many occasions has replaced the linear power supply, although the output ripple is larger than linear power, but can be reduced by filter measures, is the development trend of power supply. High frequency, high voltage and digitalization are the basic trend of the development of switching power supply in the fields of sterilization and insect control [5-7].

Therefore, the high voltage for the key components of the vegetable foliar pest elimination system as required by the project funding the research in this paper Field, comprehensive PID and pulse width modulation technology PWM design to achieve a high voltage wide range of adjustable switching power supply, and using microprocessor as the control core, can be the general battery voltage 12 V DC to 1 000 V~20 kV DC, according to the need of adjustable output voltage, to meet the needs of high voltage electric field to eliminate vegetable leaf pests.

II. SCHEME DESIGN

Working process of switching power supply: PWM (Pulse Width Modulation) pulse width modulation switching power supply makes high power transistors work through PWM signal switching between on (ON) / off (OFF), the volt-amp product on the power transistor is very small (at conduction, low voltage, large current; off, high voltage, low current), that is, [8-12] loss on the power device is small. There are two main working modes of switching power supply: positive transformation and boost transformation. This paper is designed to raise the low voltage direct current to DC1000 V~20 kV, so this paper adopts the boost transformation. The box diagram of the switching power supply principle designed in this paper is shown in Figure 1.

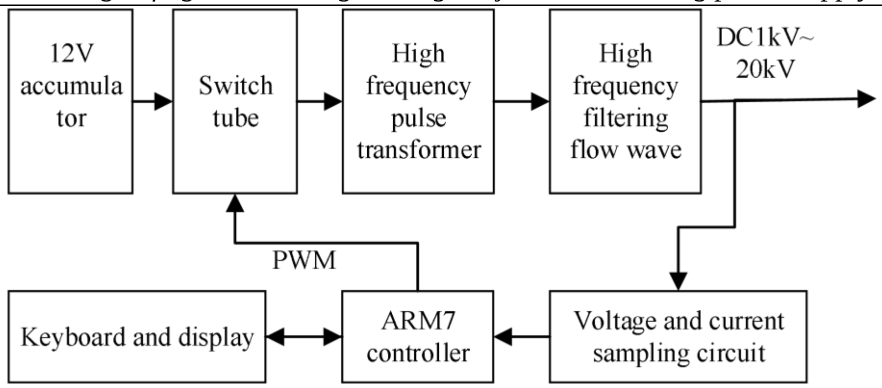

Fig. 1 Experimental setup scheme

In Figure 1, the battery is of 12 V size, which can be lithium battery or lead-acid battery. The switch tube adopts MOSFET, High-current and high-voltage MTP20N10, etc., The IGBT type can also be adopted; The basic parameters of MTP20N10 are drain to source voltage (Drain-to-Source Voltage) VDSS = 100 V, drain continuous current (Continuous Drain Current) (TC= 25℃) ID=20 A, total power dissipation (Total Power Dissipation) (TC=25℃) PD=75 W, RDS(on)=0.15 Ω. Each parameter of the selected element shall be not less than the parameter value of MTP20N10.

High-frequency transformer in the system mainly completes the electrical insulation isolation, voltage increase conversion and magnetic energy conversion between the primary and secondary functions, is an important component of the high-voltage switching power supply. In general, the high frequency pulse transformer input winding voltage is low voltage DC voltage, when the high power switch tube under the action of PWM signal, working, the high voltage DC voltage will be converted to the square wave voltage, in the high frequency pulse transformer, so by the high frequency pulse transformer through electromagnetic energy into high frequency AC voltage, and through the action of other rectifier filter circuit, the high voltage AC in the high frequency pulse output winding transformer converted into set high voltage DC voltage [12-15]. The high voltage package BSC 25-3355-55, the maximum output voltage can reach 25 kV, and contains high voltage rectifier silicon reactor to complete rectification, which can meet the needs of this study and reduce the cost.
The voltage sampling circuit is divided by the output high voltage, and then sent to the ADC interface in the microcontroller microprocessor. The maximum voltage obtained after the partial voltage is 3.0 V.

In Figure 1, the controller adopts ARM 7 series and controls the output voltage by output PWM. The SCM output voltage can be set by the keyboard circuit to display the output DC voltage for convenient setting. The voltage and current circuit is used to collect the output voltage and current and send the sampling signal to the MCU. After comparison with the set voltage, the SCM changes the PWM signal to adjust the output voltage. The output voltage is connected to the electrode array. The controller runs the PID algorithm. The PID has strong robustness (Robustness), simplicity (Simplicity) and good adaptability (Adaptiveness) for the switching power supply system, and can control the output voltage to keep stable.

III. Control Program design and implementation

According to the working principle and basic function of switching power supply [12-14], the main program flow chart of switching power supply designed in this paper is shown in Figure 2. The PID controller includes three links: proportion P (Proportional), integral I (Integral) and differential D (Derivative), corresponding to three adjustment parameters: , and . is used to adjust the dynamic deviation of the system, reflecting the current information of the system; IK is used to improve the static characteristics of the system, reflecting the accumulation of the system to the past information; is used to realize the advance control of the system dynamic change signal, which represents the speed of error change. According to Equation (1), the control error e (t) can be obtained from the setting value r (t) and the actual output y (t), the three parameters of , and can be adjusted, then the PID can be calculated, then the , and parameters of PID can be determined, and finally the control [14-15] of the output voltage can be completed. The control algorithm u (t) expression is shown in equation (2).

$$e(t) = r(t) - y(t) \tag{1}$$

$$u(t) = K_p[e(t) + \frac{1}{T_f}[e(t)\mathrm{d}t + T_D\frac{\mathrm{d}e(t)}{\mathrm{d}t}] \tag{2}$$

Where K_p is the proportional coefficient while T_f is the integral time coefficient and T_D is the

differential time coefficient.
Control program implementation:
(1) The ADC implementation is as follows:
void InitAdc (void)

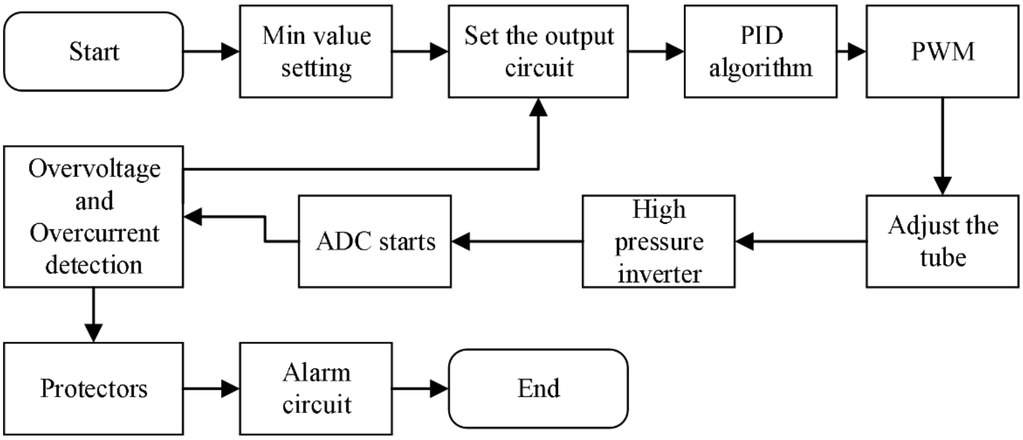

Figure 2 Flow chart of the controller master program

```
{AdcRegs.ADCTRL1.bit.ACQ_PS = 0x4;
AdcRegs.ADCTRL3.bit.ADCCLKPS =0x0;
AdcRegs.ADCTRL1.bit.SEQ_CASC = 1;
 AdcRegs.ADCTRL2.bit.INT_ENA_SEQ1 = 0x1;
AdcRegs.ADCTRL2.bit.RST_SEQ1 = 0x1;
AdcRegs.ADCMAXCONV.all = 0x0003;
 AdcRegs.ADCCHSELSEQ1.bit.CONV00= 0x0;
 AdcRegs.ADCCHSELSEQ1.bit.CONV01 = 0x1;
                AdcRegs.ADCCHSELSEQ1.bit.CONV02=0x2;
AdcRegs.ADCTRL2.bit.EPWM_SOCA_SEQ1 = 1;  // Enable SOCA from ePWM to start SEQ1
AdcRegs.ADCTRL2.bit.INT_ENA_SEQ1 = 1;  // Enable SEQ1 interrupt（every EOS）
 }
void adc_isr（）；
 {
u1=（（float）AdcRegs.ADCRESULT0）*3/65536;
 Voltage1[ConversionCount] =bian*（u1- pian）；
 u5=bian*（u2-pian）；
 ConversionCount++;
 if（ConversionCount == 128）
 {
ConversionCount = 0;
sum1=0;
for（sy=0; sy<16; sy++）
{ sum1=sum1+Voltage5[sy*8]*Voltage5 [sy*8]; }
sum1= sum1/16;
sum= sqrt（sum1）；
}
AdcRegs.ADCTRL2.bit.RST_SEQ1 = 1;
AdcRegs.ADCST.bit.INT_SEQ1_CLR = 1;
PieCtrlRegs.PIEACK.all= PIEACK_GROUP1;
}
```

(2) The PID implementation is as follows:

```
e1=U-sum;
if（e1>0.2）e1=0.2;
if（e1<-0.2）e1=-0.2;
```

```
e=e1-e2;
PID=Kp*e +Ki*e1+PIDold;
if（PID>0.9）PID=0.9;
if（PID<0.2）PID=0.2;
PIDold=PID;
e2=e1;
```

(3) The PWM algorithm is implemented as follows:

```
EPwm1Regs.TBPRD=2*2930;  EPwm2Regs. TBPRD=2*2930;  EPwm3Regs.TBPRD= 2*2930;
pp=EPwm1Regs.TBPRD>>1;
adc_isr（）;
 j=k;
t1=pp+pp*（m*sinne[j]）;
j=j+a;
if（j>t511）j=j-t512;
t2=pp+pp*（m*sinne[j]）;
j=j+a;
if（j>t511）j=j-t512;
t3=pp+pp*m*sinne[j];
k++;
j=k;
t4=pp+pp*m*sinne[j];
j=j+a; if（j>t511）j=j-t512;
t5=pp+pp*m*sinne[j];
j=j+a;
if（j>t511）j=j-t512;
t6=pp+pp*m*sinne[j];
k++;
t1=t1+t4; t2=t2+t5; t3=t3+t6;
PWM_cnt1=（Uint16）（（4*pp- t1）>>1）; PWM_cnt2=（Uint16）（（4*pp-
t2）>>1）; PWM_cnt3=（Uint16）（（4*pp-t3）>>1）;
EPwm1Regs.CMPA.half.CMPA= PWM_cnt1;
EPwm1Regs.CMPB = PWM_cnt1;
EPwm2Regs.CMPA.half.CMPA=PWM_cnt2;
EPwm2Regs.CMPB = PWM_cnt2;
EPwm3Regs.CMPA.half.CMPA=PWM_cnt3;
EPwm3Regs.CMPB = PWM_cnt3;
if（k>t510）{k=0; }
EPwm1Regs.ETSEL.bit.INTEN=1;
EPwm1Regs.ETCLR.bit.INT=1; }
```

IV. System Simulation AND results

In order to verify the rationality of the switching power supply design scheme, the designed high power voltage generation circuit of switching power supply is simulated [2-6] by using the power system simulation toolbox SimPower System in MATLAB / Simulink library. The schematic diagram of the simulation circuit is shown in Figure 3.

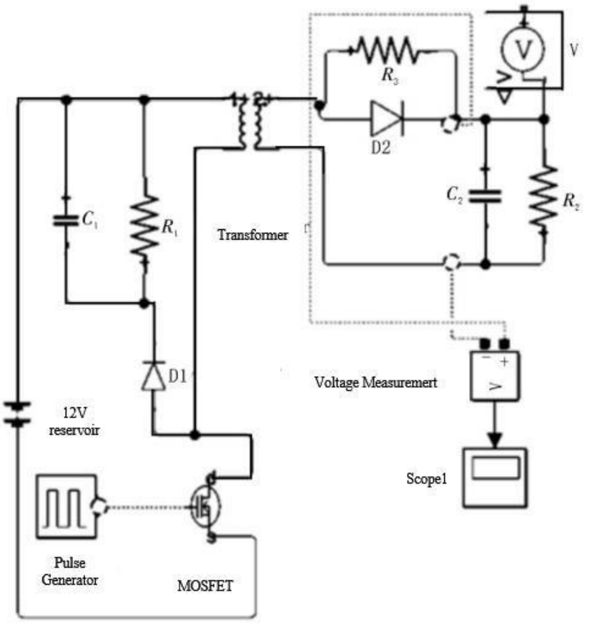

Figure 3 Switching power supply Simulink simulation circuit

Switch power supply output voltage adjustment test data (test condition is load 1 G Ω, measured resistance 6 G Ω) as shown in Figure 4.

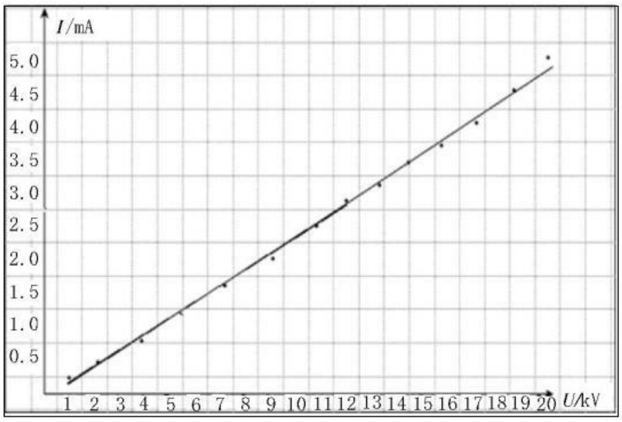

Figure 4 Test results of switching power supply

As can be seen from Figure 4, the output voltage is basically linearly variable and continuously adjustable. The adjustment range can cover 1~20 kV, and the current can cover the range of 0~5 mA, which meets the design requirements and meets the needs of the project.

V. CONCLUSION

Design to realize the high voltage wide range adjustable switch power supply, using PWM pulse width modulation technology, using ARM microprocessor as a controller, MOSFET as adjustment tube, large screen TV high voltage package as high voltage pulse transformer, with simple structure, small volume, light weight, low cost, strong load capacity, the characteristics of output voltage range continuous adjustable. The main performance indexes are: the working frequency is 30 kHz; the output high voltage is 1~ 20 kV; the output current is 0 ~ 5 mA; the working efficiency is more than 90%. It can meet the needs of high voltage electric field to prevent and control vegetable leaf pests, and can also meet the needs of other systems using high voltageelectric field.

Acknowledgment: this work was supported by Science and Technology Project of Henan Provincial Science and Technology Department (Granted No: 222102210116), and the Ministry of Education industry and education cooperation and collaborative education project (Granted No: 202101346001, 221001221014436).

REFRENCES

[1]. Tan Zhiyuan, Ren Xianwen, Liu Ping, et al. Development of Compact 100 kV/10 kW DC High-Voltage Switching Power Supply. Electric Power Electronics Technology, 2014 (12): 44-46, 85.

[2]. Wang Yong, Han Sulin, Guo Boya. Optimization Design of High-Voltage, High-Power, Small-Volume Switching Power Supply. Power World, 2018 (2): 24-26.Sivakumar, V. and Sundaram, E. G. [2013] "Improvement techniques of solar still efficiency: A review" Renewable and Sustainable Energy Reviews, Vol. 28: pp.246–264.

[3]. Gao Zhijia. Design of High-Frequency High-Voltage Switching Power Supply for Power Plant Dust Removal. [Dissertation]. Beijing: North China Electric Power University, 2017.Franchini, G. and Perdichizzi, A. [2014] "Modeling of a solar driven HD (Humidification-Dehumidification) desalination system" Energy Procedia, Vol. 45: pp.588–597.

[4]. Wang Hongqi, Wan Gege. A Design Scheme of High-Voltage Adjustable High-Frequency Switching Power Supply. Journal of Henan Polytechnic University: Natural Science Edition, 2018 (3): 107-112.

[5]. Wang Lin. High-Voltage Power Supply Design Based on STM32. [Dissertation]. Shenyang: Liaoning University, 2015.Kabeel, A.

[6]. E. and El-said, E. M. S. [2014] "A hybrid solar desalination system of air humidification, dehumidification and water flashing evaporation: II. Experimental investigation" Desalination, Vol. 341: pp.50–60.

[7]. Ji Junpeng, Chen Wenjie, Ma Zhipeng, et al. Design of 36 kV Electron Beam Bombardment Furnace High-Voltage DC Switching Power Supply. Journal of Xi'an Jiaotong University, 2017 (8): 102-109.

[8]. Zhang Guojun, Song Feifan, Dai Guoyin, et al. Design and Simulation of High-Voltage Arcless DC Circuit Breaker. Journal of Liaoning Technical University: Natural Science Edition, 2017 (11): 1199-1203.

[9]. Mou Xiaolei. Design of 5 kV High-Voltage Switching Power Supply. [Dissertation]. Wuhan: Wuhan University of Technology, 2014.

[10]. Cong Enjia, Meng Dechuan, Deng Yufu. Design of 300 kV Miniature High-Voltage Power Supply. Electronic Technology and Software Engineering, 2018 (5): 242-243.

[11]. Liu Wanli. Research on Built-In Switch Transistor High-Efficiency DC-DC Switching Power Supply. Electronic World, 2018 (10): 141-142.

[12]. Pan Yongxiong. Switching Power Supply Technology and Design [M]. Xi'an: Xi'an University of Electronic Science and Technology Press, 2016.

[13]. Zhang Zhihai, Wang Kangyi. Design of Switching Power Supply Based on PWM Control. Automation and Instrumentation, 2016 (8): 35-36.

[14]. Wu Xiaoquan, Dai Zhenyu. Visualization Recommendation System Based on Attribute Correlation Analysis. Computer Engineering and Applications, 2018, 54(7): 251-256.

[15]. Yang Wen, Zhang Bangshuang, Ye Xin, et al. Exploration of Sensor Fault Detection Method in Distribution Network Based on Energy Balance. Automation of Electric Power Systems, 2018, 42(12): 160-165.

[16]. Zhang Bo, Hao Jie, Ma Gang, et al. Automatic Image Annotation Based on Weak Matching Probability Typical Correlation Analysis. Journal of Software, 2017, 28(2): 292-309.