DESIGN AND IMPLEMENTATION A SWITCHING MODE BIPOLAR POWER STAGE OF THE CORRECTION POWER SUPPLY

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Abstract

A bipolar power supply, which meets the internal specifications of originally correction power supplies, is designed to increase its efficiency. The power source of this power supply is designed that the working voltage mode on a dc bus is adjustable. Such voltage adjustment is conducted according to the state of current output and load. A new power switching device, which utilizes power MOSFET, giving much higher working frequency than former 60Hz, is used as an energy converting mode system of the switching power supply. This allows an increase of the correction power supply's efficiency, and significant decrease of its weight. This new designed switching power supply provides a set of bipolar current sources, and following the working voltage, it can be automatically regulated with feedback by programmable setting. Conclusions and functional characteristics are as discussed in this paper.

INTRODUCTION

This research aims to convert the linear mode of currently used 60Hz power supply to a switching mode in the correction power supply. It is clear that the volume and weight of traditional 60Hz transformer cannot be changed, and its poor efficiency is due to considerable depletion during the energy transformation. Therefore, we used a switching type of power source into the correction power supply, to replace with the traditional type of 60Hz transformer's power supply, aiming to achieve the objectives of volume miniaturization, low weight and an increase of efficiency.

The correction power supply has been extensively used for the storage ring at national synchrotron radiation research center. Thus, rapid maintenance and repair have become an important task in our team. We thereby aim to develop a correction power supply with switching power source, to achieve the miniaturization of volume, lightweight and efficiency improvement. Thus, we shall carefully examine such technical problem, as a high quality and low ripple current, produced by the correction power supplies are demanded at national synchrotron radiation research center.

The power source for the correction power supply was modified to use switching and adjustable mode of output voltage for the purpose of increasing efficiency. This modification can remarkably increase the efficiency and lower the weight of the original correction power supply.

SYSTEM TOPOLOGY DESIGN

Speaking of system analysis, it is referred to the topology diagram of Model SRR-220-25-20-IV of INVERPOWER, depicted in figure 1. As shown in the analysis of the current correction power supply, a set of positive and negative tappings, which are referenced to the ground line, and drawn from the traditional 60Hz transformer is rectified by power diode and capacitor respectively, to produce a set of positive and negative power sources. These meet the energy demand of correction power supply. The volume and weight of transformer, rectified diode, and capacitor are enormous as they are working at 60Hz.

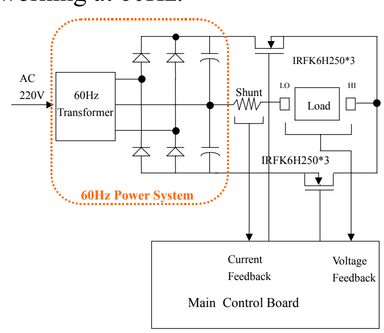


Figure 1 ：Topology diagram of INVERPOWER Model SRR-220-25-20-IV

As well as the traditional type of current 60Hz power supply, the new design of a switching power transformer must also produce a set of positive and negative power sources to meet the energy demand of the correction power supply. Since the working frequency has been improved from 60Hz to 20kHz, as indicated in table 1, the 20kHz switching power transformer has significant differences from the transformer working at 60Hz, and the volume and weight of capacitor. This is what this project aims for.

60Hz Transformer	Length 190 mm	Width 180 mm	High 220 mm	Weight 16.5 Kg
20kHz Transformer	Length 110 mm	Width 85 mm	High 100 mm	Weight 1.4 Kg

Table 1： Comparison of high and low-frequency transformers in terms of weight and volume

Regarding to the system topology of the switching type power supply, the maximum output power of correction power supply is below 500W, and if we took factors of conversion efficiency into account, we would be able to develop a switching type of power supply possessing the potential of 800VA~1000VA. Of those current switching type of power supply's topology, the most appropriate topology is Push-Pull with gaped, and the basic topology for switching type of power transformers is illustrated in figure 2.

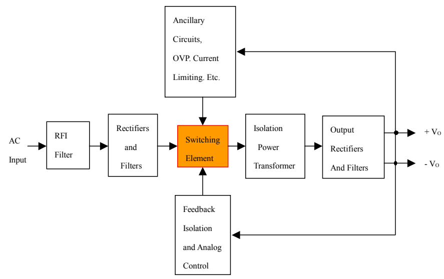


Figure 2 ：Basic topology of switching type power supply

POWER TRANSFORMER DESIGN

First of all, it must set up the specification of switching type of transformers that are described in the following:

1.Input Voltage: AC 220V +/-10%
2.Topology: Push-Pull with gaped
3. Output Voltage: AC 18V~20V (Maximal)
4. Switching Frequency: 20kHz~25kHz
5. Output Current: 20Amper
6. Output Power: 500W
7. Temperature Insulation: H Class
8. Core Material: MMG
9. Ae=8.6cm^4
10. Air gap: 0.1mm

The winding design for the switching type of transformer was conducted based on former described specifications. The coil number of primary winding is shown in the formula (1), and the value is substituted into the equation.

$$N_P = \frac{V_P \Delta t \times 10^8}{A_e \Delta B} = \frac{V_P T_{ON} \times 10^8}{A_e 2 \Delta B} \qquad (1)$$

$$= \frac{310 \times (50/2) \times 10^{-6} \times 10^8}{A_e \times 2 \times 2000} = 22.52$$

We can select the coil winding number N_P=22

Design and examine winding coefficient:

1.Limit the Wire Current Density <= 400 Circular mils/A
2.The wire diameter of No.17 AWG (1.04mm^2) can be obtained by referring to table Ip < 3Amper.
3.According to skin effects and a transformer's winding methods, we selected No.25AWG*10TS (0.162mm^2*10>>1.04 mm^2) that meant we used ten No.25AWG enamel-insulated wire at H class to wind collaterally, and so that the transformer can work safely at 20kHz. Since the transformer's topology is Push-Pull with gaped, there would be two sets of winding at one time, and a technique of intermediate tapping would be used.

Design the secondary coil winding's number:

1. For secondary Ns=2TS
2.When the maximal current value of secondary winding is Is=20Amper, two sets of coil material of No.25AWG*20TS are used for shunt winding. The diameter of effective current flow is calculated as 0.162mm^2*20*2=6.48 mm^2.
3.Examine the Wire Current Density = 300 Circular mils/A, and if it is less than 400 Circular mils/A, it can acquire safe operating performance.

DETAILED CIRCUIT DESIGN

We use an UC-3856 controller to control the switching type of power sources, and the main controller of the UC-3856 possesses two sets of installed 1.5Amp. Power MOSFET drivers with phase difference of 180 degrees. The programming and adjustable frequency is suitable for driving Power MOSFET of 800W~1000W. UC-3856 has functions to adjusting power restriction, and belongs to current mode controllers. Therefore it can automatically balance the equilibrium between the voltage and second of switching transformers, which are produced by sandwiching winding, without leading to transformer saturation.

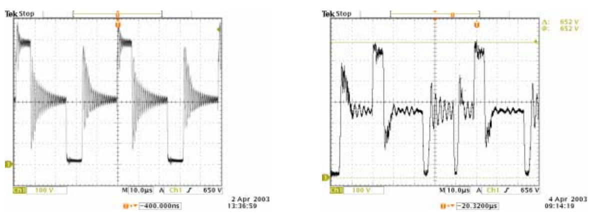
In the controller's circuit of switching power supply, an internal power supply for the main control board in the correction power supply is used to drive UC-3856 controller. Thus, this way allows a more simplified circuit, and reduced the assisting winding sets of switching transformers. Such design is more appropriate to meet the requirement of the correction power supply. Furthermore, the feedback signal applies the mode of analogical adjustment that can accurately control the output voltage, and allow the switching power supply to obtain a better efficiency.

Regarding to the signal feedback circuit of output voltage, the voltage feedback signal is the minimal signal to detect positive and negative output voltage. Here it does not matter whether if the load is at positive or negative side of the output power supply, it can still detect to obtain correct feedback and provide a programming signal. It further can provide UC-3856 controller signals for adjustment, and there by voltage can precede automatic programming adjustment to give high performance in efficiency.

DATA MEASUREMENT AND RESULTS

The working frequency of UC-3856 controller is 20kHz after circuit setting, and first of all, the dynamic voltage waveform of MOSFET should be observed. As seen in figure 3, the voltage ripple is produced when the MOSFET is switched, and in the circuit, one can know the over light and overweight of snubber adjustment.

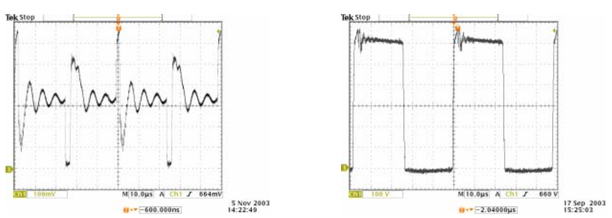
Thus, when MOSFET is switched, snubber circuit adjustment can cause voltage ripple to give different outcomes. Therefore, it is an important task to adjust upper and lower stage of snubber circuit, and besides to confirm that the MOSFET is working at 20kHz.



(Snubber over light) (Snubber overweight)

Figure 3： Voltage ripple produced when MOSFET is switched.

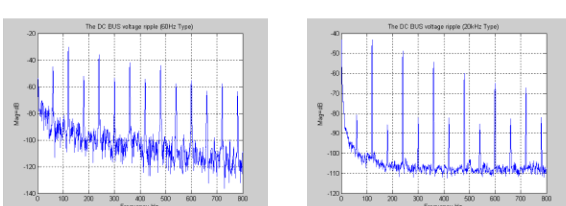
For different voltage settings and load, UC-3856 controller will automatically adjust the pulse width modulation, followed by adjusting PWM when MOSFET is switched. One can know the difference by understanding the adjustment of voltage pulse width modulation produced when MOSFET is switched, as illustrated in figure 4.



(Light load situation) (Complete load situation)

Figure 4： Adjustment of pulse width modulation produced when MOSFET is switched.

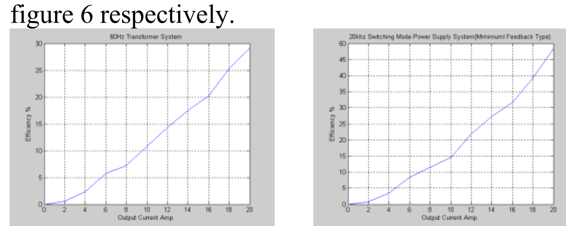
The output characteristics of voltage ripple, produced by power supply were measured in the correction power supply. Figure 5 depicts the output voltage characteristics of traditional power source and the switching type of power source. These characteristics were obtained and measured by dynamic signal analyzer. The frequency was scanned from 0~800Hz. Hence, it is obvious that the switching type of power source is more excellent than the traditional power source.



(Traditional power source) (Switching type power source)

Figure 5： Output voltage ripple characteristics

The new produced power supply was put in and measured for its input and output efficiency. The output efficiency for the traditional and switching type of power sources in the correction power supply are depicted in figure 6 respectively.



(Traditional power source) (Switching type power source)

Figure 6： Output efficiency of the correction power supply

From the comparison between the output efficiency (29%) of the traditional 60Hz transforming system power source and the output efficiency (49%) of switching type of power source in figure 6, it can be understood that the efficiency is sequentially increased, from 29% up to 49% as well as significantly increased performance.

CONCLUSION

We designed and utilized basic characteristics of switching type of power supply to produce and replace the power source for the original correction power supply. In addition, we allowed the output voltage to conduct automatically the programming adjustment, which then greatly increased the entire working efficiency of correction power supply, and the results were exactly what we expected.

It is certainly that a linear output of correction power supply, together with programming auto-feedback circuit, will give more efficient and better performance. Thus, in future design, an idea of pre-regulator by keeping constant R_{DS} of MOSFET will be applied to further improve its efficiency. Please refer to reference paper 2 carefully.

The bipolar output of switching type transformer is a distinguishing feature in this design as a single controller is able to achieve and fit with the bipolar output controlling properties of the correction power supply.

REFERENCES

[1] GEORGE C. CHRYSSIS, High-Frequency Switching Power Supplies, McGRAW-HILL PUBLISHING COMPANY, 1989.

[2] KBL, High Efficiency Linear Power Supply With A Pre-regulator Controlled by Keeping Constant R_{DS} of MOSFET, PAC-1999

[3] Bipolar Linear Correction DC Power Supplies Model SRR-220-25-20-IV Operation Maintenance Manual.