A UPS BASED ON A NEW SPWM GENERATOR

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ABSTRACT - A new SPWM control method for Uninterrupted Power System(UPS) is presented. A triangle waveform is used as the reference signal. The desired SPWM control signal can be obtained more easily with a group of comparators. The output AC voltage can be regulated by controlling the lower reference and the upper reference of the comparators according to the feedback voltage Basic principle, an actual circuit and the experimental results on a 500W UPS for computer system is discussed as an example.

1. INTRODUCTION

Uninterrupted Power System(UPS) plays an important role in computer systems. Although micro-controllers have been introduced to the UPS. the intelligent approaches need more devices. It is worse that there is the possibility that program is interrupted by disturbance. Although a watch-dog-timer(WDT) can reset the system, the duration time of the UPS in the abnormal state is too long for the load, i.e., the computer system.

We present in this paper a new UPS whose control and protect circuit is based on analogue and logic devices, thus the circuit can be hybridized to be more compact and more reliable. When any disturbance happens, the UPS can come back to stable without delay.

A inverter is the main part in the UPS which generates a fine sine voltage from the battery when the utility line is off. The early methods to generate an AC output from a DC source is to make the output of the inverter be a rectangular waveform at a certain frequency, thus it suffers from large harmonic content. Multi-converter modules can improve the quality of the output voltage, but they need more complicated control circuits. It is known that Sine Pulse-Width-Modulation(SPWM) is a better method for an inverter[1]. The SPWM waveform is generally produced by comparing a triangle carrier with a reference sine waveform [2][3]. But it is not an easy thing to generate a fine reference sine waveform. We introduce a new method to generate SPWM waveform. Neither sine waveform nor triangle carrier is needed. A triangle waveform is used as the reference signal. The desired SPWM control signal can be obtained more easily with a group of comparators. The output AC voltage can be regulated by controlling the lower reference and the upper reference of the comparators according to the feedback voltage. Therefore, the new method has the advantage of simplicity.

2. STRUCTURE OF THE NEW UPS

The new UPS works in on-line mode with its structure shown in Fig.1.

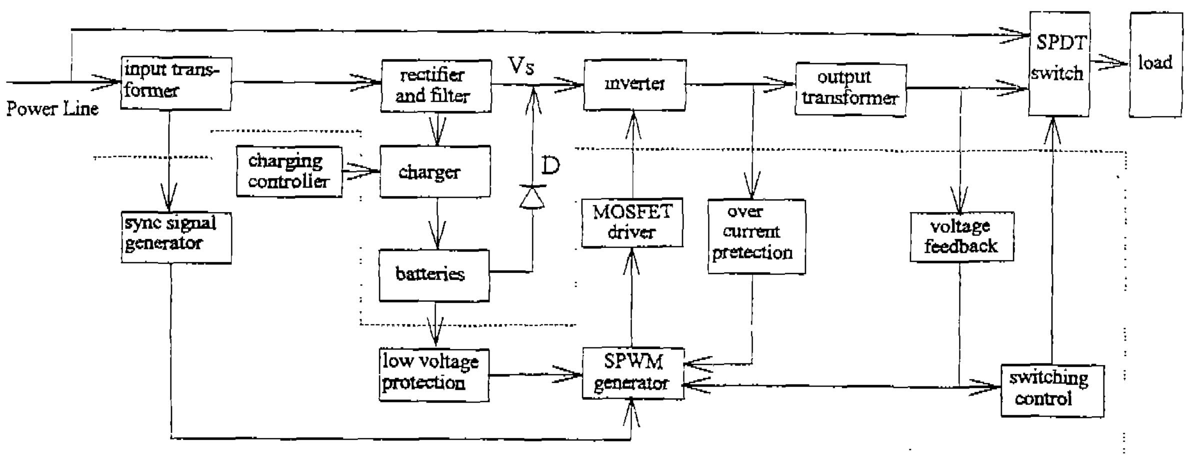


Fig.1 Structure of the new UPS

The input transformer and the rectifier provide the low DC voltage Vs for battery charging and for the inverter.

The charging controller works in a PWM mode, under the control of which, the batteries are charged with a constant current in the early period, and with a constant voltage in the end.

When Vs is higner than the voltage of the batteries, the switch D is off, the inverter is supplied by Vs. When Vs is lower than the voltage of the batteries(typically, when there is no electricity on the power line), the switch D turns on, the inverter is supplied by the batteries.

The inverter is controlled by the SPWM generator which will be detailed later.

The low voltage protection circuit can turn off the SPWM controller, if the voltage of the batteries is too low(i.e., the batteries are nearly used up) when the output power is supplied by the batteries.

The over-current protection circuit can turn off the SPWM controller, if the output current is too large, or there is an output short circuit.

The SPWM signal can be regulated according to the voltage feed-back, thus the AC output voltage of the inverter can be made rather stable.

Under the control of the switching control circuit, the SPDT switch connects the output of the inverter or the power line to the load. At most times, the load is powered by the inverter. But when the output voltage of the inverter is abnormal, either too high or too low(typically the inverter is broken-down), the load is powered directly by the electricity power line. The SPDT switch is composed of two thyristors instead of the traditional two relays, therefore the interval for switching is quite short. Because the thyristors can not be turned off immediately, two single-shot triggers in the switching control circuit are necessary to obtain the desired control logic.

The sync signal generator can produce a square waveform with the conduction ratio of 0.5, which has a frequency two times of that of the power line AC input voltage(typically 100Hz), and is in step with the power line AC input voltage. The SPWM signal is produced on the base of the square waveform. A phase-locked loop, i.e., CD4046, is used in the sync signal generator.

It is remarkable, especially for the UPS of lower power(such as 500W), that the devices in the dashed block in Fig.1 can be hybridized into a model, thus the control circuit is not only more compact but also more reliable.

3. GENERATION OF THE SPWM SIGNAL

Basic Principle

The new SPWM generator is shown in Fig.2. The 100Hz square signal, i.e., f_1, is from the sync signal generator. The symmetric triangle reference signal f_2 is produced based on f_1. Another square signal f_3 for control logic, with the frequency half of that of f_1 is produced by the frequency divider. CMP1~CMP5 are double-reference comparators, with their upper references and lower references accurately designed in order to generate SPWM signal f_4 from the triangle signal f_2. The SPWM signal f_4 is converted into two control signals f_5 and f_6, which take effect in turn to drive the two switches in the inverter to work coordinately. The topology of the inverter can be push-pull, half bridge or full bridge.

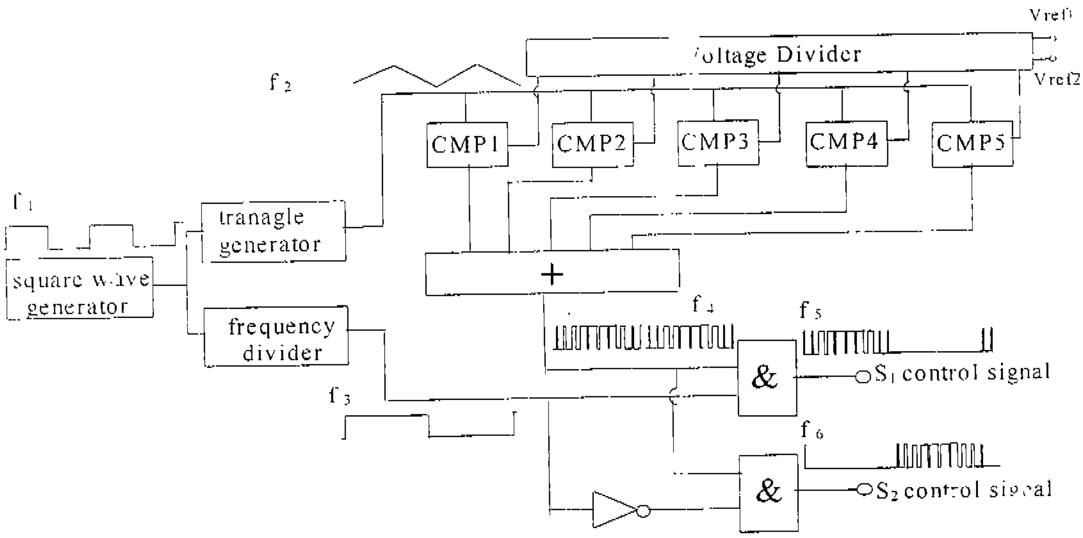


Fig.2 Structure of the new SPWM generator

Design of Comparators

In order to obtain the SPWM signal, we can divide the sine waveform in one period into N equal intervals, where N=4m(m is a positive integer). An equivalent rectangle pulse with the area in proportion to the area of the sine signal in the corresponding interval can be used as the SPWM signal. It can be proved that the width of the i-th SPWM signal is as equation(1) and (2)[1][2].

$$d_i = 2\frac{U_{Sm}}{U_{Pm}}\sin B_i \sin\frac{\pi}{N} \tag{1}$$

$$B_i = \frac{2\pi i}{N} - \frac{\pi}{N} \qquad i = 1,2\ldots N \tag{2}$$

where, d_i is the width of the i-th SPWM signal, U_{sm} and U_{pm} are the amplitude of the sine signal and the equivalent rectangle pulse, respectively. B_i is the position center angle of the i-th SPWM signal(refer to Fig.3).

Fig.3 shows the determination of the Upper reference and the lower reference of the comparators.

In Fig.3, $u_T(t)$ is the symmetric triangle signal with the amplitude of U_{Tm}. In order to obtain the rectangle signal of the desired width, the comparators must have their upper reference U_{ui} and lower reference U_{Li} . t_{Ui} and t_{Li} are the moment of U_{ui} and U_{Li}, respectively. Therefore, we have

$$u_T(\omega t) = \frac{U_{Tm}}{\frac{\pi}{2}}\omega t = \frac{2U_{Tm}\omega t}{\pi} \tag{3}$$

$$(where \quad 0 < \omega t < \pi/2)$$

$$\omega t_{Li} = B_i - \frac{d_i}{2} \qquad \omega t_{Ui} = B_i + \frac{d_i}{2} \tag{4}$$

$$(where \quad i \le N/4)$$

$$U_{Li} = u_T(\omega t_{Li}) = \frac{2U_{Tm}(B_i - \frac{d_i}{2})}{\pi} \tag{5-a}$$

$$(where \quad i \le N/4)$$

$$U_{Ui} = u_T(\omega t_{Ui}) = \frac{2U_{Tm}(B_i + \frac{d_i}{2})}{\pi} \tag{5-b}$$

$$(where \quad i \le N/4)$$

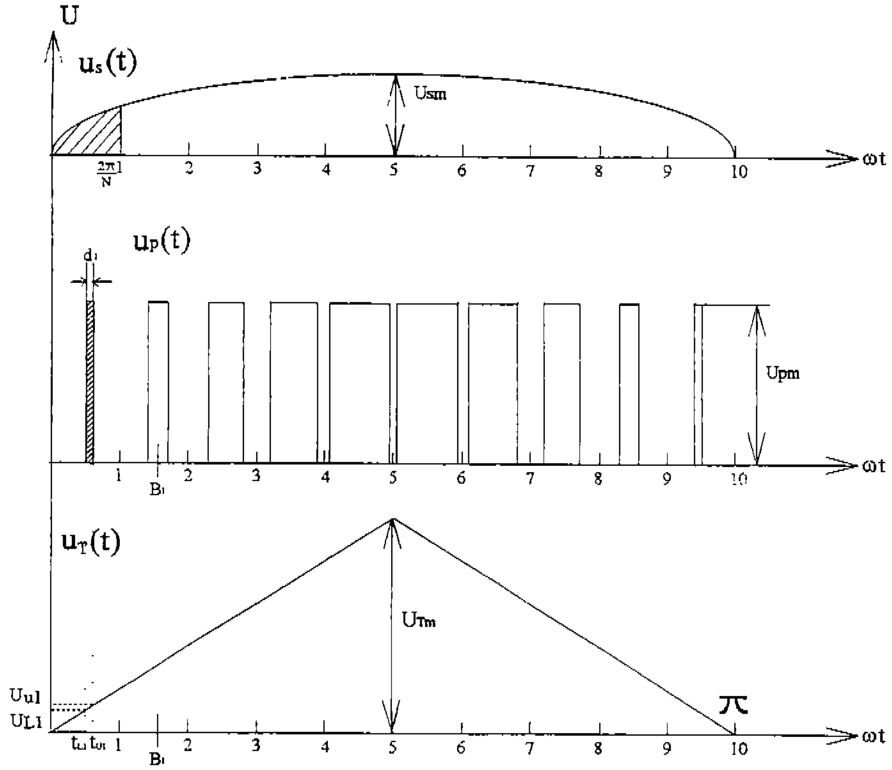


Fig.3 Determination of the Upper reference and the lower reference of the comparators

According to the symmetric characteristic of a sine signal, we have:

$$U_{Li} = U_{L(N/2-i+1)} \quad (where \quad N/4 < i \le N/2) \tag{6-a}$$

$$U_{Ui} = U_{U(N/2-i+1)} \quad (where \quad N/4 < i \le N/2) \tag{6-b}$$

$$U_{Li} = U_{L(i-N/2)} \quad (where \quad N/2 < i \le 3N/4) \tag{6-c}$$

$$U_{Ui} = U_{U(i-N/2)} \quad (where \quad N/2 < i \le 3N/4) \tag{6-d}$$

$$U_{Li} = U_{L(N-i+1)} \quad (where \quad 3N/4 < i \le N) \tag{6-e}$$

$$U_{Ui} = U_{U(N-i+1)} \quad (where \quad 3N/4 < i \le N) \tag{6-f}$$

Equation (5) and (6) are the design considerations for the comparators.

4. OUTPUT VOLTAGE REGULATION

In order to guarantee the SPWM pulse to be axial symmetry with its corresponding position center angle(otherwise, the waveform of the output voltage of the inverter would have some distortion), the design need to be accurate. The closed-loop control diagram is shown in Fig.4. To simplify the problem, we adopt two resistance networks with the same voltage-dividing-ratio K_i and two different voltage references, i.e., V_{ref1} and V_{ref2}, respectively. P_1 and P_2 are potentiometers to adjust the two references. The DC feedback voltage V_f is obtained by dividing, rectifying and low-pass-filtering the AC output voltage of the inverter. Ve, i.e., the difference of the feedback voltage V_f and the constant voltage V_G is used as the regulating signal. When the output voltage is at the desired value, V_f is designed to be equal to V_G, there is no regulation. A negative feedback takes effect when the output voltage is higher or lower than the desired value. For instance, when V_f is higher, Ve will be positive leading the lower reference of the comparators to rise and the upper reference of the comparators to drop. Because the two resistance networks are the same, the lower reference of the comparators rise the same voltage as the upper reference of the comparators drop. Therefore, the width of each SPWM impulse becomes narrow, and yet axial symmetry with its corresponding position center angle.

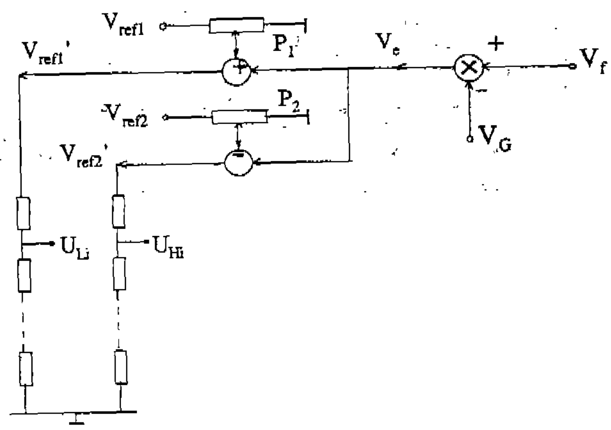


Fig. 4 Closed-loop control diagram

In the practice, we first let V_e to be zero, and make the U_{Li} and U_{Ui} to be of the designed value by adjusting P_1 and P_2, respectively. Then introduce feed back and make the output voltage stable within the whole input voltage range and within the whole load range by adjusting the intensity of the feed back voltage.

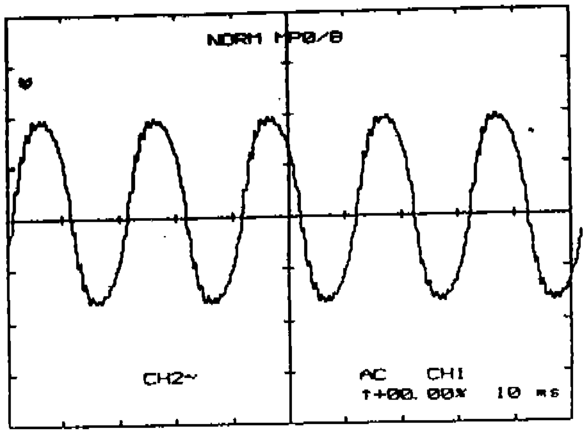
5. EXPERIMENT RESULTS

We have made a prototype of UPS of 500W adopting the technique discussed above. The voltage of the batteries is 12V. The output of the UPS is 220V AC voltage with frequency of 50Hz. The push-pull topology is used in the inverter with two MOSFET switches, i.e., MTM60N06(60A, 60V). The filter inductor and capacitor are 32mH and 6μF, respectively.

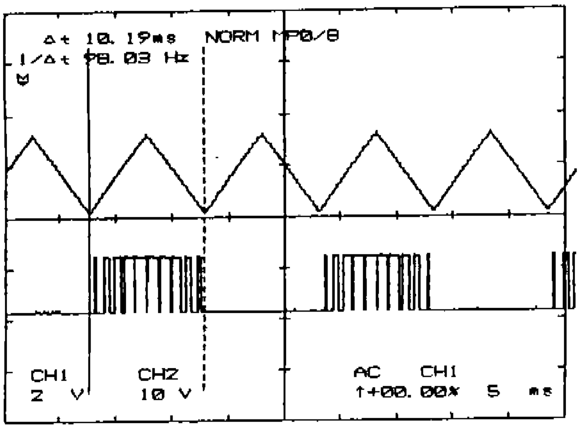
Fig.5 shows the experiment results of the prototype UPS.

6. CONCLUSION

Based on analogue and logic devices, the control and protection circuit of the UPS can be hybridized to be more compact and more reliable. The SPWM signal can be generated in a easier way by a group of comparators. Neither sine waveform nor triangle carrier is needed. The output AC voltage can be regulated by controlling the lower reference and the upper reference of the comparators according to the feedback voltage. Therefore, the new method has the advantage of simplicity. Experimental results proves the feasibility of the new method.



(a)



(b)

Fig.5 Experimental results of the prototype UPS (a)output voltage waveform (b)symmetric triangle waveform and SPWM signal

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