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Single-phase Online Uninterruptible Power Supply Based on EG8010 and IT8705

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Abstract: This paper mainly uses EG8010 and LT8705 as the central module to rectify and stabilize the AC power supply and realize the conversion of DC to AC. Use this to design AC sine wave online uninterruptible power supply (UPS). LT8705 as the central module with high performance voltage stabilization effect and multi-compatibility function, is the preferred device. EG8010 is the core device of the inverter power board, which realizes DC-AC transformation through SPWM modulation and switches the power supply with Schottky diode to realize the uninterrupted power supply of DC power even if AC power outage. The experiment proves that the expected effect can be achieved.

1. Introduction

UPS plays an important role in daily life and various industries. It can ensure the normal operation of the machine and no data loss in case of accidental power failure, unstable voltage, frequency drift, etc. UPS devices have a wide range of protection, from device monitoring designed to protect a single computer without video to large-scale equipment, which can power the entire data center or building.

UPS has been developing rapidly [1-7]. However, in the process of designing UPS, generating SPWM wave is an extremely important step, and there are many ways to generate it. Use hardware to generate sine wave and triangle wave, use sine wave as fundamental wave, triangle wave as carrier wave, input to analog op amp comparator for comparison and output SPWM wave. Due to the arbitrary focus of triangle wave and sine wave, the pulse center is not within one cycle. Equidistance will increase the cumbersomeness of calculation, making hardware frequency modulation very difficult and difficult to debug [4,6]. The use of a dedicated analog SPWM integrated module is expensive due to the limitation of the power supply voltage.

In this paper, we use the internal integrated SPWM sine generator, dead time control circuit and other multi-functional EG8010 to generate SPWM waves to drive the inverter circuit [9]. The control circuit of this scheme is simple, the amplitude and frequency of the generated SPWM is easier to control, and the quality of the generated SPWM wave is better. For voltage stabilization, we adopted a high-performance buck-boost switching regulator controller LT8705 [8]. The structural block diagram of UPS is shown in Figure 1.

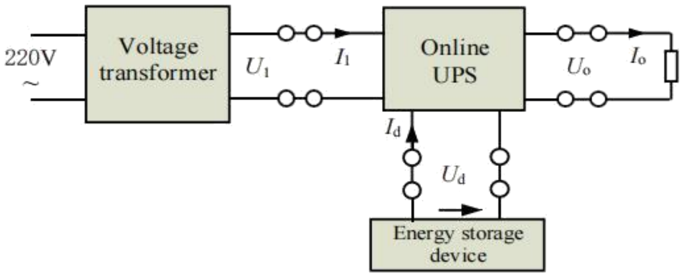

Figure 1.UPS structure diagram

2. Circuit and hardware design

2.1. Main circuit and device selection

This experiment mainly uses self-coupling transformer to transform voltage to generate 36V AC power. After r rectification and filtering, LT8705 is used for voltage stabilization. In the inverter power board, the regulated DC power is directly inputted, and the power supply interface outputs low-voltage AC.

The LT8705 is a high-performance step-down-boost switch voltage stabilization controller that operates with the input voltage above, below, or equal to the output voltage. The device has an integrated input current, input voltage, output current, and output voltage feedback loop. With the in-chip self-lifting circuit, you can drive the high-end field tube directly, simplifying the peripheral circuit. Use the internal current monitoring loop to realize the overcurrent protection function. The schematic diagram is shown by Figure 2.

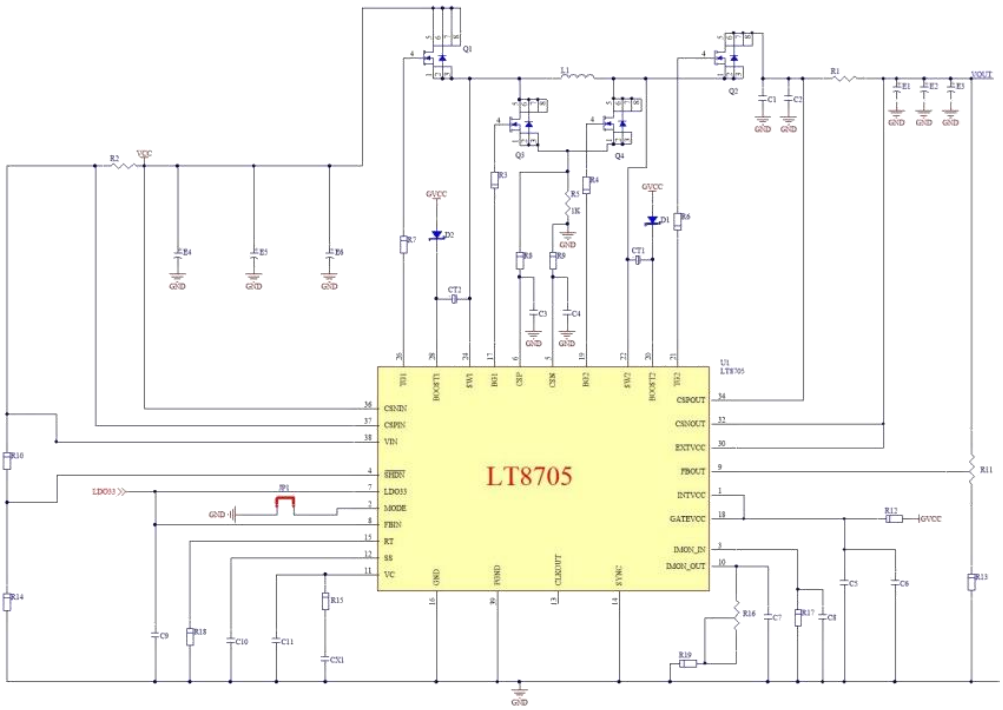

Figure 2. LT8705 circuit schematic

The inverter power board is a power backplane supporting EG8010 SPWM chip and EG2126 field effect tube driver, suitable for inverter units below 1KVA. The inverter power board has two working modes: the front stage is boosted by a high-frequency transformer DC-DC and then input high-voltage direct current to the on-board power supply interface direct inverter output mode (high-frequency mode); directly input low-voltage direct current to the board The power sup-ply interface inverter outputs low-voltage AC and then is boosted by a power frequency transformer to output high-voltage AC (power frequency mode). Ac-cording to the subject requirements, the power frequency mode is used here, and the power frequency step-up transformer is omitted for direct output. The schematic diagram is shown in Figure 3.

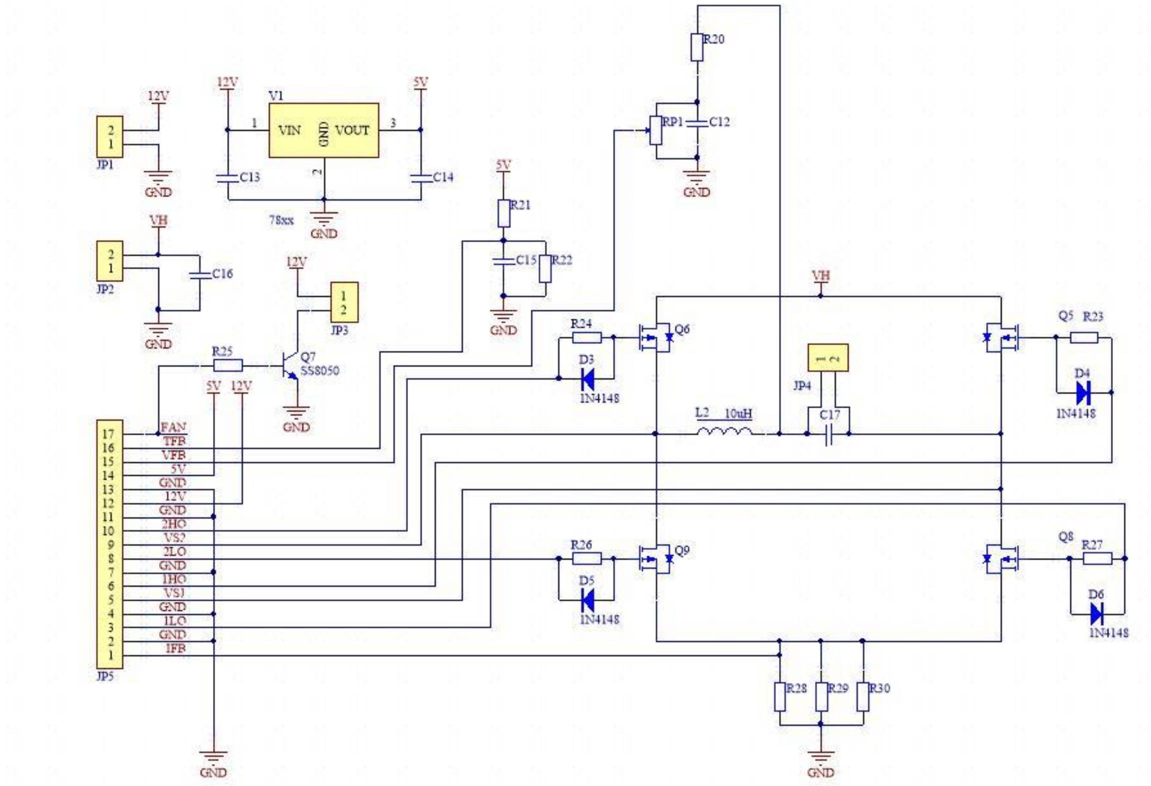

Figure 3. Schematic diagram of power backplane

2.2. Control Circuit

The formation of SPWM wave adopts EG8010. EG8010 is a digital and fully functional pure sine wave inverter generator chip with dead zone control. It is applied to DC-DC-AC two-stage power conversion architecture or DC-AC. The single-stage power frequency transformer step-up conversion architecture, with an external 12MHz crystal oscillator, can realize a pure sine wave 50Hz or 60Hz inverter chip with high precision, low distortion and harmonics. The chip adopts CMOS technology and integrates SPWM sine generator, dead time control circuit, amplitude factor multiplier, soft start circuit, protection circuit and other functions. The schematic diagram is shown in Figure 4.

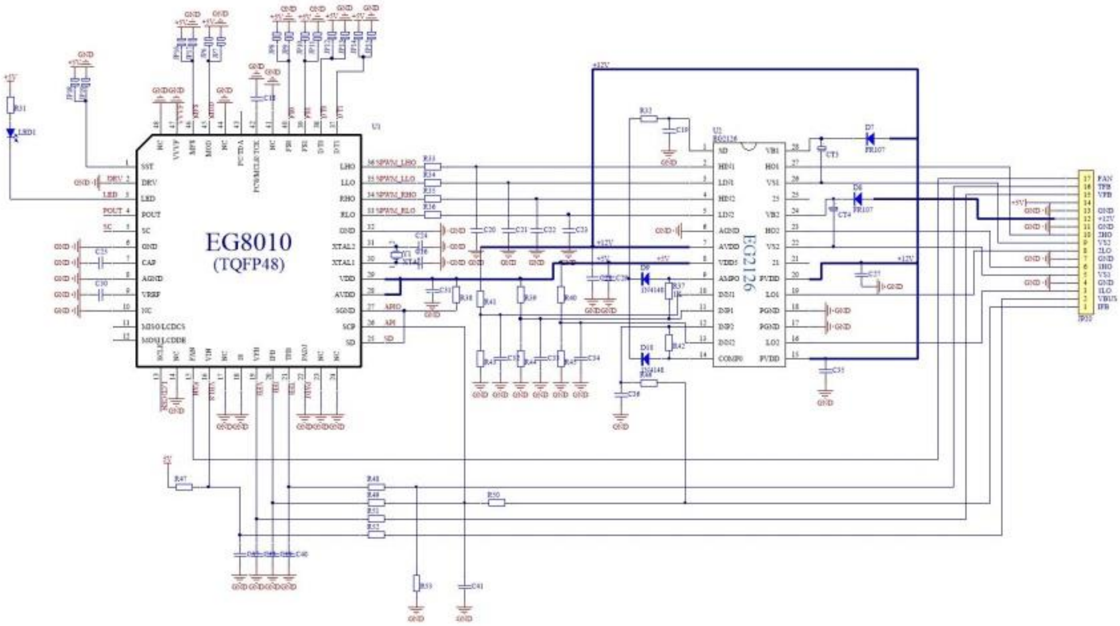

Figure 4. SPWM module schematic

2.3. Protection circuit

Use the pin IFB of the EG8010 chip to measure the inverter output load current for over-current protection detection. The reference peak voltage inside this pin is set to 0.5V. The over-current detection delay time is 600ms. When some cause causes the load current If the load current is higher than the inverter's load current, EG8010 will output SPWMOUT1 SPWMOUT4 to "0" or "1" level according to the setting state of pin PWMTYP. Turn o all power MOSFETs to make the output voltage to low level. This function is the main Protects the power MOSFET and the load. Once the overcurrent protection is entered, the EG8010 will release and turn on the power MOSFET after 16 seconds to judge the load overcurrent. The duration of the release and turn on the power MOSFET is 100ms, and it will be judged within 100ms after the release. If an over-current event still exists, the EG8010 will turn o all power MOSFET to bring the output voltage to low level, and wait for 16s to release again.

3. Theoretical analysis and calculation

3.1. Voltage stabilization control method

Using high-performance buck-boost switching regulator controller LT8705 for voltage stabilization, a four-tube synchronous recti cation topology, which can work when the input voltage is higher than, lower than or equal to the output voltage.

3.2. Improve efficiency methods

Select the appropriate switching frequency. Higher switching frequencies can reduce the volume and weight of the converter, but the loss of the switching tube also increases with the increased frequency.

$$P_{on} = \frac{1}{2} U_D I_O t_{on} f_s \tag{1}$$

$$P_{off} = \frac{1}{2}U_D I_O t_{off} f_s \quad (2)$$

Judging from Equations (1) and (2): The loss of the switching tube is proportional to the frequency. The higher the switching frequency, the higher the loss.

Therefore, comprehensively consider that the switching frequency of the previous stage regulator is 200kHz; the switching frequency of the subsequent stage SPWM module is 20KHz.

Choose the Infineon switch tube 042N10 with smaller gate capacitance and on-resistance to reduce the gate series resistance of the switch tube, optimize the PCB layout, and reduce the switching loss of the switch tube; at the same time, use three-wire parallel iron-silicon-aluminum inductors. Effectively reduce core loss.

Reasonably design the SPWM filter inductor. Since the carrier frequency of the SPWM wave is 20kHz, in order to filter the carrier frequency and higher harmonics and increase the output THD, the filter cut-o frequency is set to f_T=4KHz, and the capacitor is selected as a CBB capacitor with C_f=1uf. From the cut-off frequency formula:

$$f_T = \frac{1}{2}\pi\sqrt{C_f L_f} \quad (3)$$

The calculated inductance is about 1.5mH. Considering the efficiency requirements of the problem, the 77439-A7 type magnetic ring is selected, the winding is more compact and the copper loss is reduced.

3.3. Theoretical parameter calculation

Selection of the boost voltage inductance: With sufficient load current in the boost region, a small value inductance will cause the ripple current to increase, thereby reducing the maximum average current (I_{OUT}) that can be supplied to the load when the boost region is operating due to the limited peak inductor current. In the boost region, in order to provide sufficient load current under low VIN voltage, L should be at least [8]:

$$L_{MIN,BOOST} = \frac{V_{IN(MIN)}\frac{DC_{MAX,M3,BOOST}}{100\%}}{2f\frac{V_{RSENSE(MAX,BOOST,MAX)}}{R_{SENSE}} - \frac{I_{OUT(MAX)}V_{OUT(MAX)}}{V_{IN(MIN)}}} \quad (4)$$

The maximum current rating and inductance current ratings must be greater than their peak operating current to prevent efficiency degradation from inductance saturation. The peak inductance current in the booster area is [8]:

$$L_{MAX,BOOST} \cong I_{OUT(MAX)}\frac{V_{OUT(MAX)}}{V_{IN(MIN)}} + A\frac{V_{IN(MIN)}\frac{DC_{MAX,M3,BOOST}}{100\%}}{2Lf} \quad (5)$$

The peak inductance current when operating in the pressure relief area is [8]:

$$L_{MAX,BOOST} \cong I_{OUT(MAX)}\frac{V_{OUT(MAX)}}{V_{IN(MIN)}} + A\frac{V_{IN(MIN)}\frac{DC_{MAX,M2,BOOST}}{100\%}}{2Lf} \quad (6)$$

After calculation, choose to use 77934 type magnetic ring, wound 12 turns, the inductance is 16uH.

Load regulation S_I: Load regulation is also called current regulation. Indicates the maximum relative change in the output voltage when the load is changed within a certain range under the condition of the input voltage unchanged.

$$S_I = \frac{U_{o2}-U_{o1}}{U_o} \times 100\% \quad (7)$$

U_{o2} is the output voltage when it is empty (or light load), U_{o1} is the full load (or heavy load) and

U_o is the output voltage at rated load.

Voltage regulation rate S_U: the load remains unchanged, the relative change of the output voltage when the input voltage changes. That is:

$$S_U = \frac{U_{omax} - U_{omin}}{U_o} \times 100\% \tag{8}$$

Among them, U_{omax} is the maximum output voltage when the input voltage changes, U_{omin} is the minimum output voltage value, and U_o is the rated output voltage.

Efficiency: The percentage of the output active power P_o to the input active power P_i. That is:

$$\eta = \frac{P_o}{P_i} \times 100\% = \frac{U_o I_o}{U_i I_i} \times 100\% \tag{9}$$

Among them, U_o is the effective value of the output voltage, I_o is the effective value of the output current, Ui is the effective value of the input voltage, and I_i is the effective value of the input current.

4. Experimental methods and results

4.1. Test scheme

Use a multimeter to test the values of I_0, U_0 and U_1, observe whether its fluctuation range meets the expected requirements, and use an oscilloscope to observe whether the output waveform is a sine wave.

4.2. Test Conditions

Measure I_0 and U_1 when the input power of the self-coupling transformer is 220V alternating current, and use the oscilloscope to measure the sine wave. Measure I_0, U_0 and calculate the efficiency when the 220V AC is disconnected and replaced with 24V DC.

4.3. Test Results

1) When AC power supply, U_1=36V, output AC current I_o=1A, output AC voltage U_o=30V ±0.2V and frequency f =50 ±0.2Hz (Figure 5).

2) AC power supply, U_1=36V, I_o changes in 0.1A and 1.0A range, load adjustment rate $S_I \leq 0.5\%$.

3) AC power supply, I_o=1A, U1 changes in 29V and 43V range, voltage adjustment rate $S_U \leq 0.5\%$.

4) Under the condition of AC power supply, U_1=36V, output AC current I_o=1A, output AC voltage U_o=30V ±0.2V and frequency f=50 ±0.2Hz, the UPS output voltage is sine wave and distortion THD≤2%. After experimental measurement, the 50HZ fundamental wave amplitude is 28.2dB, the second harmonic amplitude is -26.0dB, the third harmonic amplitude is -21.5dB, and the distortion THD=0.4%.

5) Disconnect the AC power supply and immediately switch to DC (on the energy storage device side) power supply, U_d=24V, when the output AC current I_o=1A, the output AC voltage U_o=30V ±0.2V, the frequency f=50 ±0.2Hz (Figure 6).

6) DC power supply, U_d=24V, under the conditions of U_o=30V, I_o=1A, make the efficiency of the online uninterruptible power supply as high as possible. Test results are shown in (Figure 7).

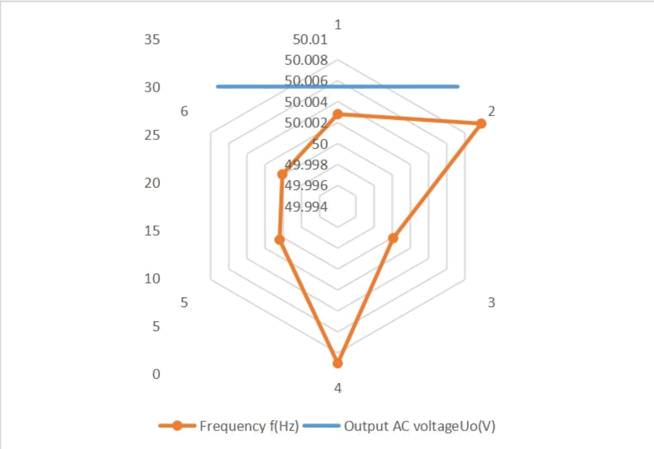

Figure 5. The output AC voltage U_o and the change of frequency f When U_1=36V, I_o=1A

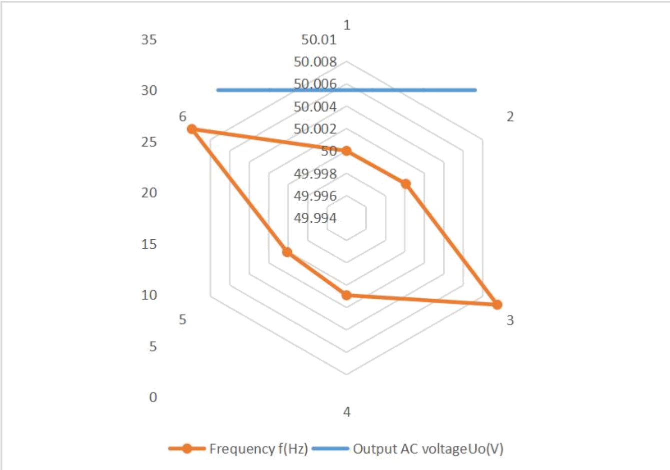

Figure 6. The output AC voltage U_o and the change of frequency f when U_d=24V, I_o=1A

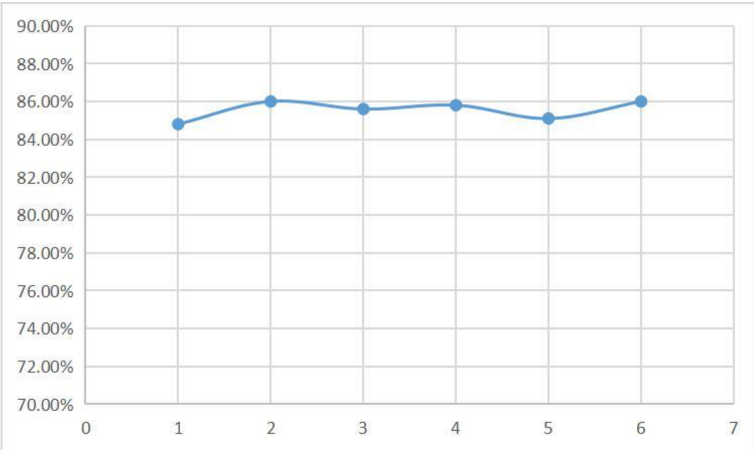

Figure 7. The change of efficiency when U_d=24V, U_o=30V, I_o=1A

5. Test result analysis

During the test, the C4 capacitor on the power backplane is changed to reduce the fluctuation value of the test voltage, and the efficiency is improved by selecting the switch tube 042N10 with smaller gate capacitance and on-resistance and selecting the appropriate switching frequency. After a series of improvements, the measurement results can have a better expected value.

In conclusion, the AC 220V voltage power supply is stepped down by a self-coupling transformer to 36V input voltage. Through automatic buck-boost and SPWM modulation, when the output AC current is 1A, the AC voltage is 30V±0.2V and the frequency is 50±0.2Hz, the output voltage of the uninterruptible power supply is sine wave at the time, and the distortion degree THD≤2%. When the output AC current changes in the range of 0.1A 1.0A, the load regulation $S_I \leq 0.5\%$, when the input voltage is between 29V and 43V. When the range changes, the voltage adjustment rate $S_U \leq 0.5\%$; switch to DC (energy storage device side) power supply, LT8705 boosts, so that the input voltage is 24V, when the output AC current is 1A, the output AC voltage is 30V±0.2V. The frequency is 50±0.2Hz, and the output voltage is 30V and the output current is 1A, so that the efficiency of the online uninterruptible power supply is as high as possible.

References

[1] B. Mwinyiwiwa, Z. Wolanski, and O. Boon-Teck. (1999). Current equalization in SPWM FACTS controllers at lowest switching rates. Power Electronics, IEEE Transactions on, vol. 14, no. 5, pp. 900-905, 1999.

[2] L. Gang, Z. Hao, C. Hui et al. (2011). A novel gang SPWM control method for six-phase induction motor. pp. 1- 4.

[3] G. Milan, M. Mohamadian, S. M. Dehghan et al. (2012). A novel SPWM strategy for single- to three-phase matrix converter. pp. 495{500.

[4] Y. Zhaoyang, Z. Kun, L. Jianxia et al. (2013). A Novel Absolute Value Logic SPWM Control Strategy Based on De-Re-Coupling Idea for High Frequency Link Matrix Recti er. Industrial Informatics, IEEE Transactions on, vol. 9, no. 2, pp. 1188-1198, 2013.

[5] A.Nayomi, S.Chandra Mouli, M.Tech. (2016). A Performance and Improvement of Optimal Voltage Control Scheme for Three-Phase Ups Systems. pp. 1282{1292

[6] Qasim Al Azze, Mohammed Hasan Ali. (2020). Design and implement of pulse width modulation with low-cost hardware in the loop. International Journal of Power Electronics and Drive System. vol. 11, no. 2, pp. 870-878, 2020.

[7] Yi Xiong. (2021). Design of single-phase online uninterruptible power supply based on STM32. CDMMS 2020. Journal of Physics: Conference Series.

[8] https://www.analog.com/cn/products/lt8705.html]product-overview. 8705f chs. pdf.

[9] http://u.dianyuan.com/upload/space/2011/06/01/1306901968-468413.pdf.