Voltage Regulation of Uninterruptible Power Supply Using PIC Microcontroller

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Abstract: Uninterrupted Power Supply (UPS) systems are used as one solution of power quality problems and to provide ultimate protection for power disturbances. Many UPS systems suffer from poor output voltage regulation especially with heavy loads. The paper discusses the design and Implementation of the UPS hardware system capable of producing continuous and constant 230V, 50Hz AC output supply. Modeling and simulation of Automatic Output Voltage Regulation System using PIC microcontroller is done using MATLAB / SIMULINK MODEL. The simulated waveforms of voltage and current are presented to verify.

Key words: Many UPS systems • UPS hardware system • MATLAB / SIMULINK MODEL

INTRODUCTION

Electric power has emerged as one of the more important elements in our daily livelihood in recent years. Power interruption leading to various outcomes has been experienced and is proven to be a threat to power consumers especially in large industries [1]. Losses in terms of life, financial and productivity are the most common aftermath of power interruption. Hence, a smart power backup and protection system has been developed. It is known as UNINTERRUPTIBLE POWER SUPPLY (UPS) that provides solutions for the failure of utility to maintain power supply. In our livelihood, there are critical or essential loads which have to be kept running all the time either in industries or applications. Therefore, slight interruption in power supply will be a major blow and may result in all sort of uninvited effects. Uninterrupted Power Supply (UPS) are used to supply clean and uninterrupted power to critical loads, e.g. Computers, Medical/life support systems, Communication systems, Industrial Controls, etc.

Components of UPS: In applications such as medical intensive care systems, chemical plant process control, safety monitors or a major computer installation, where even a temporary loss of supply could have severe consequence, there is need to provide an Uninterruptible Power Supply system which can maintain the supply under all conditions [2]. Therefore, the function of UPS is to provide an interrupt free supply of power to the A.C load, which cannot be directly fed from DC source and DC is required to be converted into AC. This provides protection against power outages as well as voltage regulation in power line during over voltage and under voltage conditions. They are also excellent in terms of suppressing incoming line transient and harmonic disturbances.

Online UPS: When a no-break supply is required, the static UPS system shown in Fig. 2 is used. In this paper, the study and test are mainly focused on the Online UPS with the general configuration which has an inverter that operates continuously and its output is directly connected to the essential loads. In this system, main AC supply is rectified and the rectifier delivers power to maintain required charge on the batteries. Rectifier also supplies power to inverter continuously which is then given to AC load through filter and normally-on switch. In case of main supply failure, batteries at once take over with no break of supply to the critical load. No dip or discontinuity in the illumination is observed in case of no-break UPS [3].

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In case inverter failure is detected, the load is switched on to the main AC supply directly by turning on the normally-off static switch and opening the normally-on static switch. The transfer of load from inverter to main AC supply takes 4 to 5 ms by static transfer switch as compared to 40 to 50 ms for a mechanical contactor. After inverter fault is cleared, Uninterruptible Power Supply is again restored to the load through the normally on switch. The batteries are now recharged from the main supply by adjusting the charger at maximum charge rate so that batteries are charged to their full capacity in the shortest possible time.

The standby batteries in the UPS system are either nickel-cadmium (NC) or lead-acid type. NC batteries have the following advantages:

- The electrolyte does not emit an explosive gas when charging
- NC batteries cannot be damaged by over charging or discharging, these have therefore longer life.

Cost of NC batteries is, however, two or three times that of lead-acid batteries. The time period for which a battery or a battery-bank can deliver power to load through inverter at the required voltage level depends upon:

- The size of the batteries
- Nature of the load

**Analysis of Output Voltage Inbuck Regulator:** The voltage across the inductor L is, in general,

\[ e_L = L \frac{di}{dt} \]

Assuming that the inductor current rises linearly from I1 to I2 in time t

\[-V_a = L \frac{(I2-I1)}{t1} \]

\[ t_1 = \frac{\Delta I}{(V_s-V_a)} \]

and the inductor current falls linearly from I2 to I1 in time t2,

\[-V_a = -\frac{L\Delta I}{t2} \]

\[ t_2 = \frac{\Delta I}{V_a} \]

Where \( \Delta I = I2 - I1 \) is the peak-to-peak ripple current of the inductor L. Equating the value of \( \Delta I \) in equation in (1) and (3) gives

\[ \Delta I = \frac{(V_s-V_a) t1}{L} = \frac{V_a t2}{L} \]

Substituting \( t_1 = Kt \) and \( t_2 = (1-k)T \) yields the average output voltage as

\[ V_a = V_s t1 / T = K V_s \]

Assuming a lossless circuit, \( V_s I_s = V_a I_a = k V_s I_a \) and the average input current

\[ I_s = k I_a \]

The switching period T can be expressed as

\[ T = \frac{1}{f} = t_1 + t_2 = \Delta I L / (V_s - V_a) + \Delta I L / V_a = \Delta I L V_s / V_a (V_s - V_a) \]

Which gives the peak-to-peak ripple current as

\[ \Delta I = \frac{V_a (V_s - V_a)}{f L V_s} \]

\[ \Delta I = V_s k (1-k) / f L \]

Using Kirchhoff’s current law, we can write the inductor current \( i_L \) as

\[ i_L = i_C + i_O \]

If we assume that the load ripple current \( i_O \) is very small and negligible, \( \Delta I L C = \Delta V_C \).

The average capacitor current, which flows into for

\[ t_1 / 2 + t_2 / 2 = T/2, \text{ is} \]
\[ I_c = \Delta I / 4 \]

and the ripple voltage of the filter is given by,

\[ \Delta V_C = V_s k(1-k) / 8LCf^2 \]  

(10)

The buck regulator requires only one transistor, is simple and has high efficiency. The di/dt of the load current is limited by inductor L. However, the input current is discontinuous and a smoothing input filter is normally required.

**V Analysis of Automatic Output Voltage Regulation Using PIC Microcontroller:** The circuit design shown above is used to convert the AC supply from the main supply into DC to charge the battery pack and also as input voltage to the Buck Regulator.

Since the inverter is a free-running inverter (works all the time), therefore by controlling the firing duty of the buck regulator, the output voltage of the inverter is made variable. In general the ‘Automatic Output Voltage Regulation Feed back’ has been employed to maintain inverter output at 12V AC. If the primary winding of the step-up transformer is somehow maintained at 12V AC the secondary output should be in the region of 230V AC. If the detected inverter output voltage, \( V_a \) is lower than 12V AC, then the ‘Automatic Output Voltage Regulation’ System will act to increase the PWM duty cycle of the buck regulator so that the output of the inverter will increase as well. However, if the Detected value of \( V_p \) is higher than 12V AC, then the microcontroller will reduce the PWM firing duty cycle of the buck regulator in order to reduce the output voltage of the inverter.

**RESULTS**

In order to obtain the voltage regulation the above MATLAB/SIMULINK model is to be verified. The above simulation shows that when the input voltage is less than \( V_{\text{REF}} \) the microcontroller will respond by increasing the firing duty cycle of the buck regulator, while the duty cycle will decrease if the input voltage becomes more than \( V_{\text{REF}} \). Applying these pulses with changeable duty cycle to the gate of the chopper, a variable dc voltage could be obtained to adjust the out ac voltage. The amplitude of the output voltage is constant.
Fig. 5: Simulation Model of the Control Circuit

Fig. 6: Inverter Output Voltage without Voltage Regulation Control (Vin > Vref)

Fig. 7: PWM Inverter Output without Voltage Regulation Control (Vin > Vref).
Fig. 8: Buck Regulator Output without Voltage Regulation Control (Vin > Vref)

Fig. 9: Inverter Output with Voltage Regulation Control

Fig. 10: PWM Inverter Output with Voltage Regulation Control
CONCLUSION

Thus the automatic output voltage regulation using PIC Microcontroller is acheived. The reliability and effectiveness of the system has been determined and the voltage regulation has been improved by using this system.

REFERENCES

