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Design of Online Ups System with Over Voltage, Under Voltage and Phase Out Protection

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Abstract: *Uninterruptible power supplies (UPS) play an important role in interfacing critical loads such as computers, communication systems, medical/life support system and industrial controls to the utility power grid. They are designed to provide clean and continuous power to the load under essentially any normal or abnormal utility power condition. Among the various UPS topologies such as online UPS, offline UPS and line interactive UPS, online UPS are widely used. In this paper hardware implementation of single phase 50Hz, online uninterruptable power supply with over voltage, under voltage and phase out protection have been carried. Atmega32 microcontroller is the heart of the system and controls entire system. By programming the microcontroller using embedded C, SPWM pulses to drive H-bridge are generated. By alternating switching switches of two legs of H-bridge alternating 9V DC voltage is converted into 9V Ac voltage. Output of H-bridge is given to step up transformer to step up the voltage to 220V, 50Hz.The microcontroller is so programmed that at every instant it checks the voltage that is supplied to the load through sensors. At any instant if it detects that there is over voltage, under voltage or phase out, microcontroller acts to isolate the load from the power source by sending tripping signal to relay. Once relay isolates the load from the power source, microcontroller supplies the load through the charged battery. Battery supplies the load until the power supply voltage reaches normal value of voltage.*

Keywords: *Online UPS,Offline UPS , Lineinteractive UPS SPWM, microcontroller ATMEGA32, Embedded C.*

I. INTRODUCTION

An uninterruptible power supply (UPS), uninterruptible power source or sometimes called a battery backup is a device which maintains a continuous supply of electric power to connected equipment by supplying power from a separate source when utility power is not available. A UPS is inserted between the source of power (typically commercial utility power) and the load which is protected. When a power failure or abnormality occurs, the UPS will effectively switch from utility power to its own power source almost instantaneously [1]-[2]. While not limited to any particular type of equipment, a UPS is typically used to protect computers, telecommunication equipment or other electrical equipment where an unexpected power disruption could cause injuries, fatalities, serious business disruption or data loss [3]. UPS units come in sizes ranging from units which will back up a single computer without monitor (around 200 VA) to units which will power entire data centers or buildings (several megawatts). Larger UPS units typically work in conjunction with generators [1]-[8].

Conventional UPS topologies can mainly be categorized into three different types:

1. Off-line
2. line-interactive and
3. On-line [1].

In offline UPS under normal operation, a small amount of power is being converted from AC to DC to maintain battery charge. When input AC power goes out of specification, the inverter converts the DC power to AC to support the load. When the input power goes out of specification, there is a power disturbance in output voltage as the power failure is detected, the relay operates, and the output inverter turns on to begin to supply the load [1]. Though offline UPSs are very inexpensive and has high efficiency normal operation has following disadvantages [1]-[3].

- The offline UPS is normally only applied to single-phase (workstation-level) non-critical loads
- Its limitations, especially the generator incompatibility make it unsuitable for three-phase applications.
- Its application is limited for only low power applications

Line interactive resembles the offline UPS topology, but inserts a transformer or inductor in series between the utility power source and the load [10]-[12]. This inline inductor enables the UPS inverter to “interact” with incoming power and provide a measure of power conditioning to the load. This “buck-and-boost” circuitry helps with high and low input voltage conditions. Like the offline UPS, the line-interactive UPS can be inexpensive and efficient because they only support the entire critical load during power disturbances, and only for the duration of the battery. The line interactive UPS has following drawbacks [1]-[3]:

- Dynamic load changes cause power to be extracted from the battery. The resulting frequent hits on the battery can shorten battery life.
- Line-interactive UPS cannot completely isolate the critical load from the input line without operating on battery.
- Small perturbations in frequency and power quality can get passed directly to the critical load
- It can’t be used for high power applications [6]-[9].

Among different types of UPS systems, the on-line UPS is the superior topology which not only overcomes the draw backs of the offline and line interactive ups but also has performance, power conditioning and load protection. Incoming AC power is rectified to DC power to charge battery of the UPS. The output inverter takes the DC power and produces regulated AC power to support the critical load. Battery is charged during normal operation. When the input power is out of specifications the batteries provide power to support the inverter and critical load.

Following are the advantages of online UPS

- The critical load is completely isolated from the incoming AC input power.
- The critical load is always being supplied by the output inverter, which is always being supplied from

the internal DC battery. When input power fails, there is no transitional sag in the output voltage because the inverter is already operating on DC input.

- The output inverter usually contains a step up or an isolation transformer. This enables the UPS to be electrically isolated and provide common mode noise protection for the load.
- A fault on the input line causes the UPS to go to battery power, but the UPS rectifier will not allow power from the DC battery to flow upstream [6], [8], [10] & [11].

II. PROPOSED BLOCK DIAGRAM

Block diagram of the proposed online UPS system with over voltage, under voltage and phase out protection using ATMega32 microcontroller is shown in Fig 1. The block diagram mainly consists of following important blocks:

ATMega32 microcontroller: It acts as the heart of the system. It controls and monitors entire system. The main function of this microcontroller is to generate SPWM signals. These signals are given to H-bridge switches to convert dc voltage to ac voltage. Microcontroller also takes care of the protection. It protects the load from over voltage, under voltage and phase out conditions by sending a tripping signal to relay. After relay isolates the load from supply the load is now supplied from battery unit.
Due to the fluctuations of energy sources, which impose stringent requirements for inverter topologies and controls.

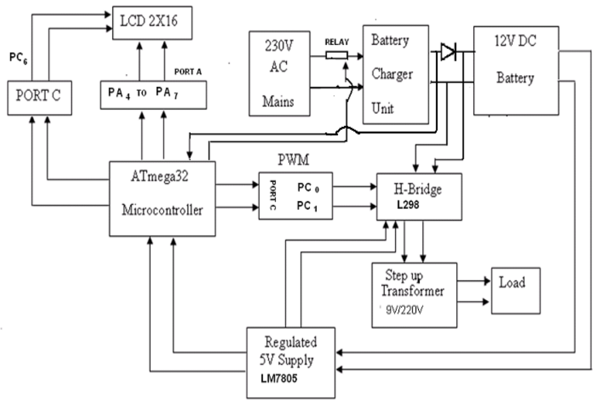


Fig 1: Block diagram of ONLINE UPS using AT-Mega32 microcontroller.

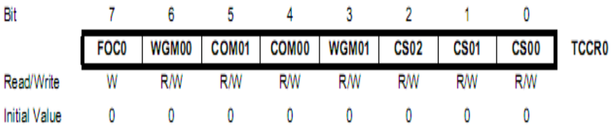
The function of an inverter is to change direct current (DC) input voltage to a symmetric alternating current (AC) output voltage of desired magnitude and frequency. When the main power is not available UPS uses batteries and inverter to supply AC power. A rectifier is used to recharge the battery used when the main power is back. Transformer is used to step up the voltage across the h-bridge to 220V [1]-[8].

In the present work design of online UPS system with over voltage, under voltage and phase out protection is taken up. The hardware prototype is implemented using Atmega32 microcontroller as control circuit. Microcontroller generates SPWM signals in order to drive H-bridge and to protect the load whenever there is change in voltage specifications through relay.

In the present work sinusoidal pulse width modulation (SPWM) technique is used to control the switches of the H-bridge. This technique is widely used in inverter to digitize the power so that a sequence of voltage pulses can be generated by the on and off of the power switches. The pulse width modulation inverter has been the main choice in power electronics, because of its circuit simplicity and rugged control scheme [9]. SPWM techniques are characterized by constant amplitude pulses with different duty cycle for each period. The width of this pulses are modulated to obtain inverter output voltage control and to reduce its harmonic content. In the present work is to replace the conventional method with the use of ATmega32 microcontroller. It is also low cost and has a small size of control circuit for the single phase H-bridge inverter [9]-[12].

III. FLOW CHARTS AND DESIGN DETAILS

ATmega32 can operate at a maximum frequency of 16MHz. In the present work 1 MHz frequency is selected. Timer/counter control register (TCCR0) is an 8 bit register. The register description of TCCR0 is as shown in Fig 2.



Bit	7	6	5	4	3	2	1	0	
	FOC0	WGM00	COM01	COM00	WGM01	CS02	CS01	CS00	TCCR0
Read/Write	W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

Fig 2: Register description of TCCR0

In the present work only bit 1 (CS01) is used. For TCCR0=2, CS01 (clock select) is, $F_C/8 = 1MHz/8 = 125$ KHz

Total time period is calculated by eqn. 1.

$$T = \frac{1}{f} = \frac{1}{125\ KHz} = 8\mu s \qquad (1)$$

To get 50Hz output time period is given from eqn. 1.

$$T = \frac{1}{50} = 20ms$$

50% Duty cycle is selected, duty cycle is given by eqn. 2.

$$D = \frac{T_{ON}}{T} \qquad (2)$$

where, T_{ON} = ON time

$$0.5 = \frac{T_{ON}}{20ms}, \quad T_{ON} = 10ms\ \&\ T_{OFF} = 10ms \qquad (3)$$

10ms time period is decomposed to reduce the harmonic content. The graphical view of switching pulses is as shown in Fig 3.

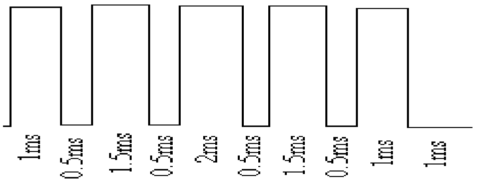


Fig 3: Graphical view of switching pulses.

To load 1ms, 0.5ms, 1.5ms in program it should be divided by 8μs we get,

$1ms = \frac{1000\mu s}{8\mu s} = 125;\ 0.5ms = \frac{500\mu s}{8\mu s} = 62.5;\ 1.5ms = \frac{1500\mu s}{8\mu s} = 187.5$ (4)

For 8 bit timer maximum value is 255(decimal). To load 125, 62 and 187 into timer/counter (TCNT0) it should be subtracted from 255. The obtained values are preloaded to get sinusoidal pulse width modulation. The dead time for the PC2 and PC3 switching pulse are loaded.

The dead time is set as 1ms which is acceptable for various types of power transistor. Typically, the switching devices consume only a few nanoseconds to operate as a switch. This delay time is necessary to avoid the damage on the inverter circuit during the switching pair transition.

The flowchart explaining sinusoidal pulse width modulation signal generation is as shown in Fig 4. The flowchart explaining the over voltage, under voltage and phase out protection is shown in Fig 5.

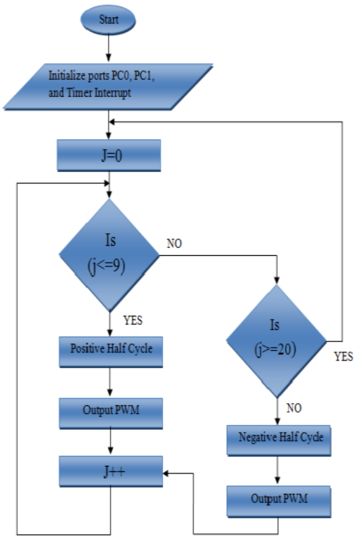


Fig 4: Flow chart for SPWM generation

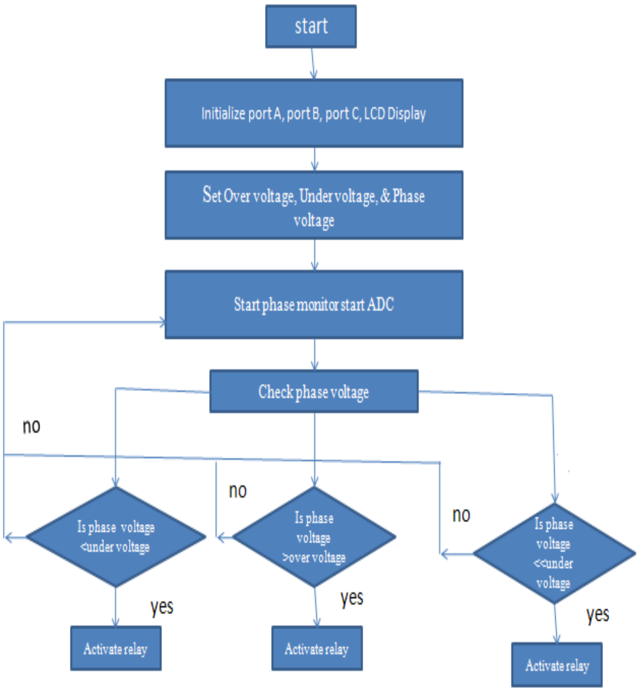


Fig 5: Flow chart for over voltage, under voltage and phase out protection

IV. INVERTER DESIGN

Design of 50 Watt Inverter, assuming efficiency of the inverter to be 98%

Efficiency = P_o / P_{in}; (4)

$P_{in} = P_o/0.98$;

$=50/0.98$;

P_{in} = 51 Watts;

Where,

P_{in} = DC input power to the inverter

$= V_{dc} * I_{dc}$;

P_o = AC output power of the inverter

Since the input DC voltage (V_{dc}) is varied from 12.5-14V, the range of input DC current (I_{dc}) is 4A to 3.64A.

Assuming the output power factor of the inverter to be 0.8;

Therefore the output power of the inverter

$(P_o) = V_{rms} * I_{rms} * \cos\phi$; (5)

Since the output voltage of the inverter (V_{rms}) = 220V;

The output current of the inverter (I_{rms}) = 0.284Amps.

V. Experimental Results And Analysis

Complete fabricated hardware set up is as shown in Fig 7.

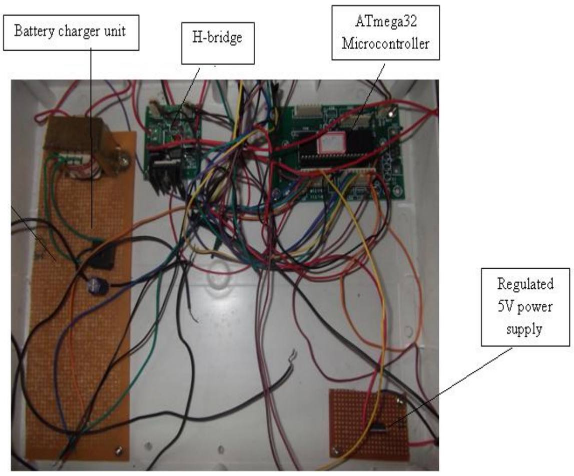


Fig 7: Complete fabricated hardware set up

The output waveform across two legs of the H-Bridge is shown in Fig 8. The out of H-bridge is given to the step-up transformer. The output voltage of step up transformer is 219V. The PWM output obtained across H - Bridge was of 50Hz with train of pulses switched at a frequency of 500Hz.

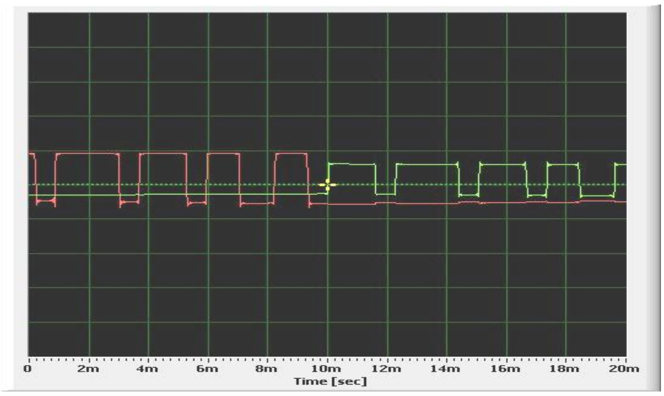


Fig .8: Output waveform across the two legs of the H-bridge

Fig 9 shows the experimental setup of project work with 15W compact fluorescent lamp (CFL) connected across step-up transformer secondary as a load. The waveform for the same is shown in Fig 10 from the waveform it can be seen the even under load the PWM output across H-bridge was almost similar to that of No load condition.

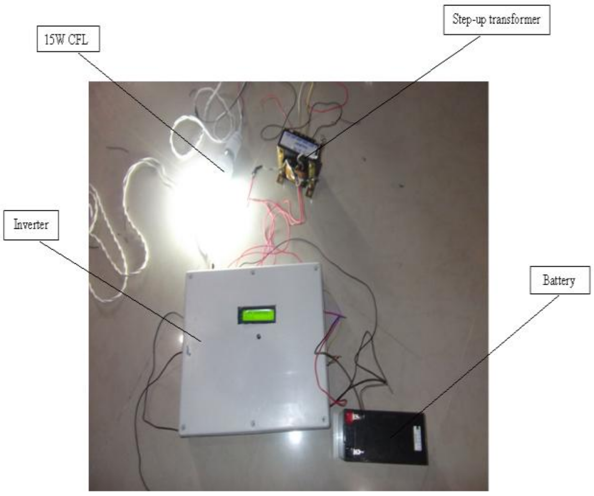


Fig 9: Snapshot of complete hardware with 15W CFL as the load

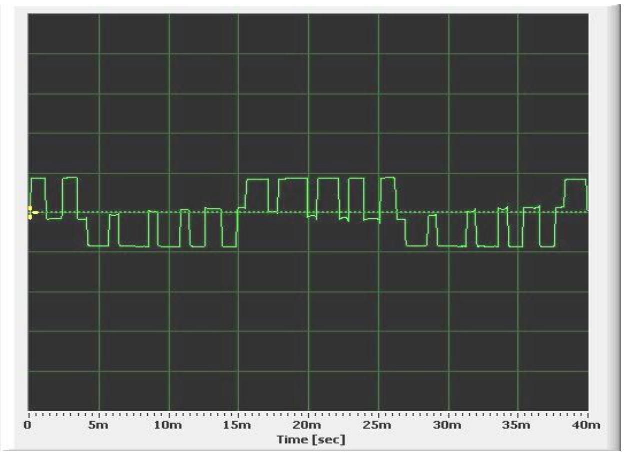


Fig 10: PWM output across H-bridge with load of 15W CFL

The various readings of CFL with variation in load is tabulated in Table 1. From this table it can be observed that the designed online UPS works efficiently well under full load condition.

Table 1: Readings of CFL as a load

SI. No	CFL(W)	V_{dc}(V)	I_{dc}(A)	P_{dc}(W)	V_{rms}(V)	I_{rms}(A)	P_{ac}(W)	%η
1	15	12.6	2.8	35.28	218	0.11	23.98	67.97
2	30	12.5	3.2	40	216	0.14	30.24	75.6
3	40	12.4	3.5	43.4	213	0.18	38.34	88.34
4	45	12.00	3.6	44	210	0.2	42	93.33

Plot of power versus efficiency is as shown in Fig 11, from which it can be observed that as the load increases the efficiency increases.

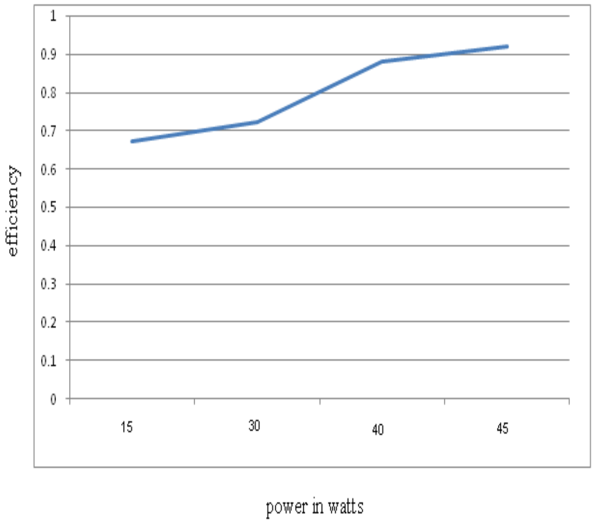


Fig 11: Plot of power versus efficiency

The hardware was also tested for over voltage by setting the nominal voltage of 180V. On supplying a voltage of 220V to the system, the microcontroller senses the over voltage through sensors and sends the tripping signal to relay and correspondingly relay acts and isolates the load from the supply. The load is now supplied by battery until the supply voltage comes close (i.e±2% tolerance) to nominal voltage which is set in the microcontroller.

The Hardware is tested for phase out and under voltage by setting the nominal voltage of 240V. When a voltage of 220V is applied to the system, the microcontroller sense the under voltage through sensors and sends the tripping signal to relay. Relay acts correspondingly and isolates the load from the supply. The load is supplied by battery until the supply voltage comes close to nominal value set in the microcontroller.

VI. CONCLUSION

In the present work, online ups system with over voltage under voltage and phase out protection has been implemented using ATmega32 microcontroller and H-bridge.

Important conclusions that are drawn out of the investigations in the present work are:

- Output waveforms of the UPS with and without load were found to be satisfactory and were in accordance with the design.
- Pulse width modulation (PWM) circuit is implemented in a single board ATmega32 microcontroller, which makes system reliable, compact.
- In addition, with the high programming flexibility, the design of the switching pulse can be further altered easily without any further changes on the hardware.
- H-bridge based on L298 integrated circuit is used which gives better efficiency and makes the system compact.
- Working of online ups with power supply on and with power supply off where found out to be satisfactory.
- The hardware designed isolates the load from the supply in case of over voltages, under voltages and phase outs. The battery supplies the voltage supply under those conditions. Thus supplying continuous supply to the load.

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