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Design and Construction of 1kVA Inverter

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Abstract: *The design and construction of a 50H_Z, 240V 1kVA inverter is primarily based on an inverter circuit which inverts the D.C. source voltage from a battery, AC voltage for AC powered appliances. The overall operation of this system comprises inter connections of many sub-circuits to give optimum performances. The sub circuit include; the oscillator circuit, PWM circuit, driver circuit, low battery/overload shutdown circuit, charging control/soft charging circuit, surge protection circuit, changeover/power supply circuit, and the output circuit (MOSFET and transformer section). This project incorporates monitoring circuit that employs visual display components such as light-emitting diodes and voltmeter to communicate the state of the system to the user.*

Keywords: *transformer, MOSFET, light-emitting diode (LED), battery, optimum performance*

1. Introduction

An inverter is a device that changes D.C. voltage into A.C. voltage. A direct current (D.C) is a current that flows in only one direction, while an alternating current (A.C.) is that which flows in both positive and negative directions.

At the early stage, sun was the source of energy for generating power. Due to the inadequacy of the power generated through this source, there was a need to find other ways to improve the power supply when the generating station could not meet the demand of the people.

As the technology advances, the hydroelectric generation was developed, gas firing generating station, and wired tubing methods of generating power supply were developed. In spite of all these developments, there was still failure in electrical power generation as a result of obsolete equipment at the generating stations.

There was still need to find alternative for solving the problem. As a result of this, some options like alternators, inverters and others were developed. The electrical inverter is a high power electronic oscillator. It is so named because early mechanical AC to DC converters was made to work in reverse, and thus was "inverted", to convert DC to AC.

The inverter performs the opposite function of a rectifier formed in the late nineteenth century through the middle of the twentieth century; DC to AC power conversion was accomplished using rotary converters or motor-generator sets (M-G set).

In the early twentieth century, vacuum tubes and gas filled tubes began to be used as switches in inverter circuits. The most widely used type of tube was the thyratron.

The origins of electromechanical inverters explain the source of the term inverter. Early A.C to D.C converters used an induction or synchronous AC motor direct – connected to a generator (dynamo) so that the generators commutator reversed its connections at exactly the right moments to produce DC.

A later development is the synchronous converter, in which the motor and generator windings are combined into one armature, with slip rings at one end and a commutator at the other end only one field frame.

The result is either AC – in, DC – out with an M-E set, the DC can be considered to be separately generated from the AC, with a synchronous converter, in a certain sense it can be considered to be mechanically rectified AC" Given the right auxiliary and control equipment, an M-G set or rotary converter can be run "backwards", converting DC to AC. Hence an inverter is an inverted converter.

There have been a large number of articles written concerning power conversion in recent years. This can be attributed in part to the rise in popularity of high voltage DC transmission systems. And their integration with existing AC supplies grids.

Transformer: It is an inductively coupled circuit used for transmitting alternating current energy. It is also used for matching impedance between the generator and the load. It makes use of mutual inductance in which a current flowing in a coil produces a varying electromagnetic wound over the primary coil.

Most transformers are used to step-up or step down voltage or current. The number of turns on the primary winding is usually different form that of Secondary. However, an isolation transformer provides secondary voltage and current that is same as that of primary voltage and current, because both winding have the same number of turns, (Expect for resistive losses). These transformers prevent the transfer of unwanted electrical noise from the primary to the secondary winding.

The primary and secondary windings of conventional transformer for electronic application are wound on tubular bobbin (insulated spool that serves as a support for the coil) made of plastic and other insulated materials. The wound bobbins are then enclosed by iron or steel cores in the shape of figure start of "E" and "I" shaped laminated metal sheets, assembled through and round the wound bobbins. The laminations are then clamped down to form a rigid assembly; some transformers have plastic shrouds to insulate the windings from the core. Both primary and secondary windings can be wound on the same bobbin, but it is now common practice, to wind the primary and secondary windings separately on a split bobbin, to improve electrical isolation. The primary and secondary terminals may be connected to rigid pins on the bobbin that also functions as printed circuit board mounting pins.

Mosfet: Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is a three terminal device they can be used either as an amplifier or as a switch. MOSFETs are classified as enhancement a depletion types.

Battery: It is a d.c. power source to electrical or electronic equipment or devices that make use of it. Battery is being made available as direct source of energy. It is therefore necessary to select a reliable battery for optimum performance.

Light Emitting Diode: It radiates optical energy when forward biased. LED is divided into base on the type of optical energy it radiates. The visible LED provides a useful means of indicating the state of a circuit and is therefore used as an indicator. In order to use visible LED as an indicating there is a need for the use of a protective resistor, which serves as a potential divider as shown below.

The invisible/infrared LED radiates infrared light when forward biased. It is used in conjunction with the photodiode phototransistor to form a sensing system as in the remote control circuit.

2. INVERTER DESIGN AND CONSTRUCTION

The inverter is a two operation modes device, the inverting and the charging modes.

The inverting mode comprises of the oscillator, the driver, the output (MOSFET) section, the PWM section, low battery / overload protection circuit, and the transformer.

The charging mode implements the transformer, the FET's (internal diodes) and the charging control circuit.

A third operation mode is the changeover modes for switching between the two aforementioned modes at times of auto-back up for power failure and power restoration for the charging process. This mode implements a delay circuit, electromagnetic relays and power supply circuit.

3. TRANSFORMER DESIGN

A transformer is a device that couples two AC circuits magnetically and provides electrical isolation between the circuits while allowing a transformation of voltage and current from one circuit to another i.e. it is mainly used for voltage and current transformation and hence we made use of current voltage transformers in this project.

The Generated E.M.F in a Wounded Transformer

In observing an ideal transformer with secondary opened and the primary connected to a sinusoidal alternating voltage V1, the potential different causes an alternating current to flow in the primary since primary coil is purely inductive and has no output but draw the magnetizing current I only .And this I will function as to magnetized the core in the secondary .It is small in and lag voltage V_1 by 90^0. It therefore produces an alternating flux that is proportional to the current inputs. This flux is linked by both primary and secondary windings .Thus; this leakage(s) produced a mutually induced e.m.f E_2 in secondary winding that anti-phase with V_1 and has magnitude proportional to rate of change of flux and the number of secondary turns.

Let N_1=Number of turns in primary, N_2=number of turns in secondary

The transformation ratio, $K= N_1/N_2$

The equation for the voltage and current transformation of a transformer is given by

$K= V_2/V_1= I_1/I_2$

F=Frequency of A.C input (Hz)

Maximum flux in core (Webbers) =B*A

Average rate of change of flux =maximum. Flux divided by 1/4F. (Wb/s or Volt.)

Now rate of change of flux per turn means induced e .m .f in Volt

Thus Average e.m. f /turn =4*F*max. Flux

Since the flux is sinusoidal, r.m.s =form factor*Average e.m.f /turn

But form factor =r.m.s value /Average value=1.11, Then r.m.s value of

E.m.f =1.11*4F*max. Flux =4.44F*max. Flux , But max .flux =Bm*A

r.m.s value of E.m .f in primary turn (Tp) =4.44F*Bm*A*Tp

NOTE: Bm is assumed to be 15000Wb/m. F=50 Hz

By introducing stacking factor (10^{-8}) and T_p factor (0.9) then we have

Number of turns per volt, $N_T.V^{-1}= 7/A$

4. CHOICE OF TRANSFORMER'S COMPONENTS

The power Rating for the Inverter transformer (KVA) =1.0KA , E_2=12V

Assuming the efficiency of transformer =85%

Then Input rating =output /Efficiency=1000VA/0.85=1176VA

$I_p = P_I / V_P$ $V_P = 260V$

$I_p = 1176 / 260 = 4.5A$

$I_s = P_o / V_s$ $V_s = 12V$

$I_p = 1000 / 12 = 83.3A$

For practical design of inverter transformer

Number of turns per volt for both primary and secondary winding is given by;

$N_T.V^{-1}= 7/A$

Where A is the area of transformer former in sq. inch

Former area A is 2.3inch by 1.5inch = 3.45sq.inch

$N_T.V^{-1}= 7/3.45=2.03$

$N_T.V^{-1} = 2$ (approximate value).

Primary Winding

Charger tapping winding turns

$N_{p1} = N_T.V^{-1} * E_1$ $E_1 = 220V$

$N_{p1} = 2 * 220 = 440$turns

Inverter (out) tapping winding turns

$N_{S2} = N_T.V^{-1} * E_3$ $E_3 = 260V$

$N_{S2} = 2 * 260 = 520$turns

Difference of Inverting and Charging turns = 520 – 440 = 80turns.

For the primary windings, charging tapping is brought out after 440 turns and an addition 80 turns is made for the inverter out tapping.

Secondary Winding

Secondary turns $N_s = N_T.V^{-1} * E_2$ $E_2 = 12V$

$N_s = 2 * 12 = 24$turns. (Bifilar winding)

SWG Estimation

Standard Gauge Weight, SGW, can be estimated as follow;

Considering conduction current density J (with fixed value of $2.5A/mm^2$) and windings coil current.

For $I_p = 4.5A$, the corresponding guage from tables is 24SWG and

For $I_s = 83.3A$, the corresponding guage from tables is 13SWG

Fig 9 shows the inverting transformer and its tapping voltage.

5. 50 Hz FREQUENCY OSCILLATOR SECTION

The generation of 50 Hz frequency by the oscillator section is based on the application of a PWM controller IC SG3524. The IC has the following under listed features which makes it excellent for the application.

- Complete PWM power control circuitry
- Single ended or push – pull outputs
- Line and load regulation of 0.2%
- 1% maximum temperature variation
- Total supply current is less than 10mA
- Operation beyond 100KHz
- Application 0˚C to +70˚C

6. SG3524 DESCRIPTION

It is a monolithic IC that contains all the control circuitry for a regulated power supply inverter or switching regulator. Included in a 16-pin dual – in – line package is the voltage reference, error amplifier, oscillator, pulse width modulator PWM, pulse steering flip-flop, dual alternating output switches, current limiting and shutdown circuitry. Fig. 1 below shows the pins definition of the IC.

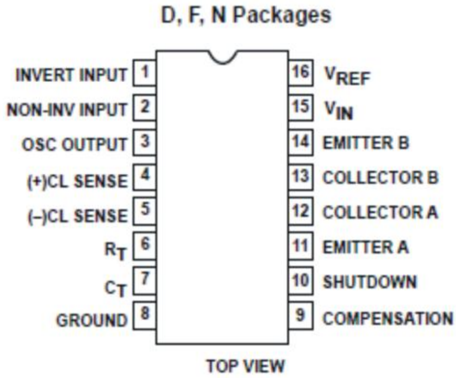

Fig. 1. *SG3524 pin configuration*

7. THEORY OF OPERATION

Voltage Reference

An internal series regulator provides a nominal 5V output which is used both to generate a reference voltage and is the regulated source for all the internal timing and control circuitry. This reference regulator may be used as a 5V source for other circuitry. It provide up to 50mA of current itself and can easily be expanded to higher current with an external PNP

Oscillator

The oscillator in the SG3524 uses an external resistor (RT) to establish a constant charging current into an external capacitor (CT). While this uses more current than a series-connected RC, it provides a linear ramp voltage on the capacitor which is also used as a reference for the comparator. The charging current is equal to 3.6V ÷ RT and should be kept within the approximate range of 30µA to 2mA; i.e. $1.8k<R_T<100k$.

The range of values for C_T also has limits as the discharge time of C_T determines the pulse-width of the oscillator output pulse. This pulse is used as a blanking pulse to both outputs to insure that there is no possibility of having both outputs on simultaneously during transition.

8. THE OSCILLATOR SECTION

The schematic diagram of the oscillatory section is as shown in fig. 2. IC1 SG3524 is used to generate the 50 Hz frequency required to generate AC supply by the inverter. Battery supply is connected to the pin-15. Pin-8 of the IC1 is connected to negative terminal of the battery. Pin-6 and 7 of IC1 are oscillator section pins.

The frequency produced depends on the value of the capacitor and resistor at these pins. The pin-6 timing resistor is a combination of a fixed resistor and a preset VR1 so that the value of the output frequency can be set. Signal generated by the oscillator section of IC1 coupled to the flip-flop section of IC1. This section converts the incoming signal into signal with opposite polarity. In a two signal with opposite polarity, when the first signal is positive, the second signal will be negative and vice versa. This process is repeated 50 times per second, i.e. an alternating signal with 50 Hz frequency is generated inside the flip-flop section of the IC1.

The 50Hz frequency alternating signal is output at pin-11 and 14 of IC1. This alternating signal is called 'MOS drive signal' having a value between 3.5V and 5.5V.

The oscillator frequency is given by;

$$F = 1.44/\ (RC)$$

For R_T=140K C_T=0.1µF

F = 50Hz (approx.)

9. DRIVER SECTION

MOS drive signal from pin-11 and 14 of IC1 are coupled to base of transistors T1 and T2. This result in the separation of the signal into two different channels and an amplification of the signal to a

sufficient level output from the transistors emitter. The resulting MOS drive signal at emitter of T_1 and T_2 is coupled to the gate of each MOSFET in the first and second MOSFET channels respectively.
The driver section made up of T_1 and T_2 circuit is incorporated into the oscillator

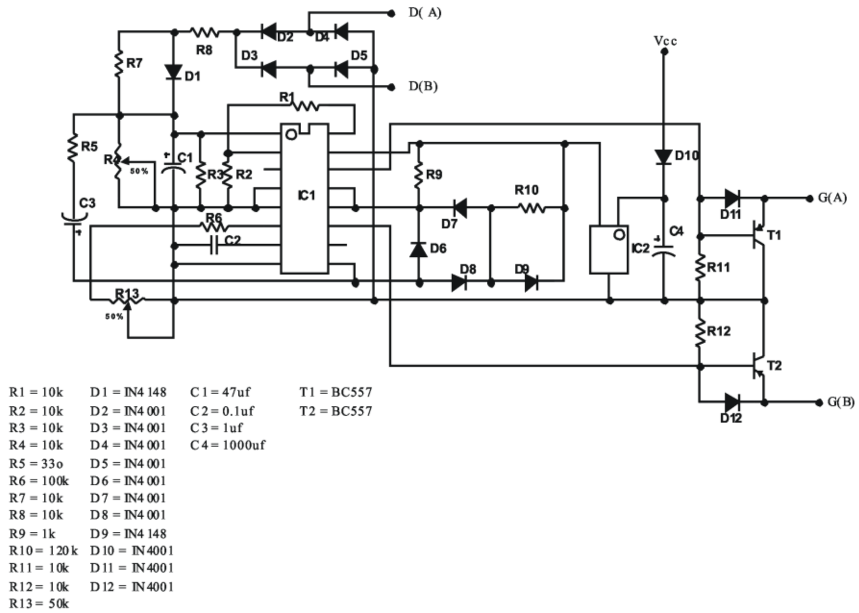

Fig 2. *Oscillator Circuit Diagram*

10. OUTPUT SECTION

The 50Hz alternating MOS drive signal reaching the MOSFET channel separately results in the channels being alternatively ON and OFF.
Drain (D) of all the MOSFET of one channel is connected together and one end of the inverter bifilar winding is connected to this connection. The same is done to the second channel and the other end of the inverters winding. Positive terminal of the battery is connected to the centre tapping of the bifilar winding.
Source (S) terminal of each MOSFET is connected to the negative terminal of the battery. Because polarity of the 50Hz MOS drive signal at pin-11 and 14 are alternatively different, current flows through the first half and second half of the transformer's bifilar winding alternatively.

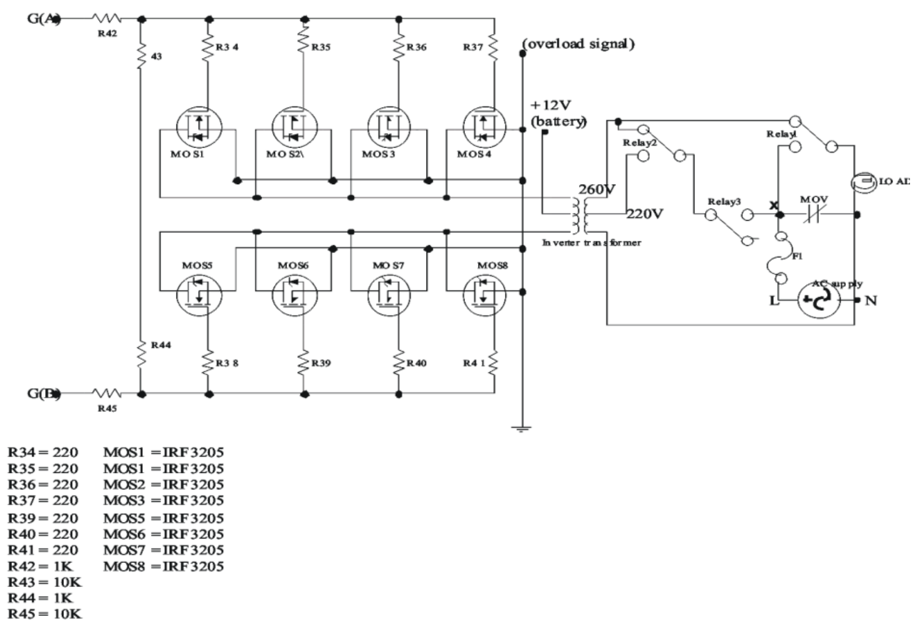

Fig.3. *Output Section Change Over Circuit*

The alternating current flowing will induce an AC current of 50Hz in the 260V tapping of the transformer. This tapping is connected to N/O-2 terminal of relay. When the AC mains is not available, pole P-2 of the relay is connected to N/O-2 terminal and thus the AC voltage produced by the inverter reaches the inverter output socket. The output section changeover circuit is as shown in fig. (3).

11. PULSE WIDTH MODULATION PWM SECTION

PWM is used to keep the inverter output to a constant 220V AC irrespective of a change in the load value connected to the inverter output socket. PWM is realized by feeding back the AC supply generated by the inverter to the PWM IC1 to keep the pulse width output from pin-11 and 14 constant. To provide feedback to the PWM controller IC, a bridge rectifier circuit made of four diodes (D2, D3, D4 and D5) is connected to the drain of the MOSFET channels. The DC voltage from the bridge rectifier is filtered by a 10µF capacitor and given to pin-1 of PWM IC through a potential divider circuit made of 10k and PWM adjustment preset VR2.

The PWM circuit has also been incorporated into the oscillator schematic diagram as shown in fig. (2). Pin-1, 2 and 9 are three pins of an internal Op-Amp, pin-1 and 2 are input pins and pin-9 is the output pin. Pin-1 is given the feedback signal; pin-2 is given 2.5V regulated supply as reference voltage through voltage divider circuit of two 10K resistors. The reference voltage is taken from pin-16 of the PWM IC_1. Pin-9 is internally connected to the section that controls the width of the oscillating frequency. Change in signal at pin-9 will result in a change in the width of the output frequency and this will always bring back the inverter output to its original 220V.

12. LOW BATTERY / OVERLOAD PROTECTION CIRCUIT

The low battery and overload protection circuit is a protection circuitry that protects the battery from being over drain and inverter’s transformer and MOSFET from being damaged respectively. The low battery and overload shutdown circuit are built upon Op-Amp comparator application.

Overload Protection Circuit

The overload protection circuit uses two Op-Amps A and C made of pin-6, 7, 1 and pin-10, 11 13 of IC2 (LM339) respectively. It also uses two transistors T_3 and T_4. Pin-6, 7 and pin-10, 11 are input pins for A and C respectively while their outputs are pin-1 and pin-13 as such. The schematic of the overload shutdown circuit.In overload condition, an “overload sensing voltage” that is greater than reference voltage set at pin-7 (by voltage divider circuit of 47k and 4.7k preset VR3) is generated at the shunt connected at the MOSFET source. This sensing voltage reaches pin-6 of IC2 and thus the Op-Amp ramps out a low signal called “overload signal” to bias T_3 through 22k resistor. This results in 6V at the collector of T_3 that is given to pin-10 of IC_2.

Op-Amp C of IC_2 compares the 6V at pin-10 and the reference voltage at its pin-11 set at 5V (from pin-16 of IC_1) to ramp out a low signal (overload signal) to bias overload transistor T_4 through 4.7k resistor to give a 4V overload signal at the collector of T_4.

The 4V-overload signal at the collector of T_4 is used to

- Switch on overload indicator LED
- Shutdown the inverter by giving overload signal to the shutdown pin-10 of PWM controller IC1.

The overload sensitivity (i.e. adjustment) is set by preset VR3. The overload circuit diagram is as shown in fig. 4

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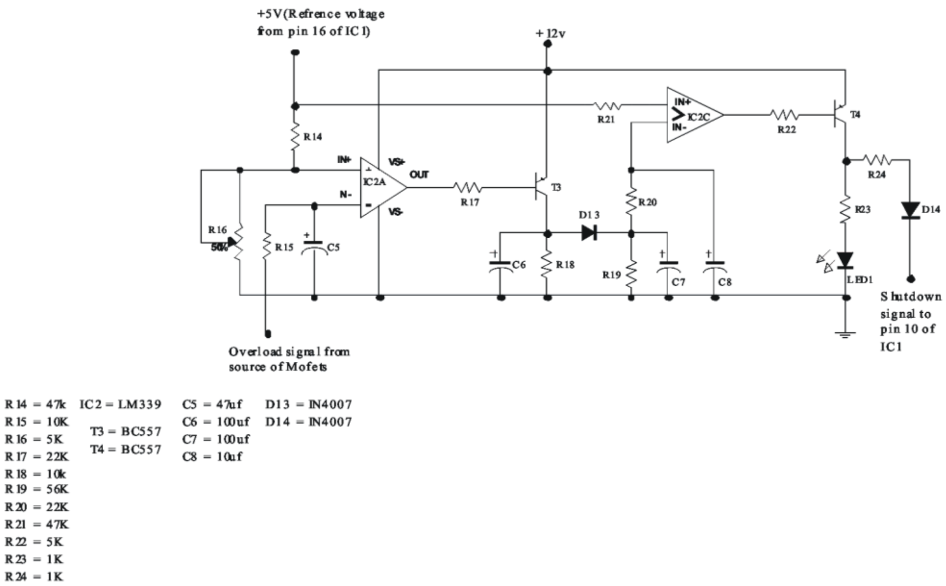

Fig. 4 *Over Load Circuit Diagram*

Low Battery Protection Circuit

In low battery condition, an Op-Amp B made of pin-4, 5, and 2 of IC_2 (LM339), T_5, SCR Q1 and low battery indicator LED is used. Pin-4 of IC_2 is given a constant reference voltage of 5V (from IC_1's pin-16) through 47k. Pin-5 is given positive supply from the battery through 47k, 10k, 10µf, and 4.7k preset VR4 network.

When the battery voltage goes lower than 10V, the voltage reaching pin-5 of IC_2 becomes lower than voltage at pin-4 of IC_2. This result in a low voltage at pin-2 of IC2 which thus biases transistor T_5 and a "low battery signal" is output at the transistor's collector.

The low battery signal is given to the gate of SCR Q1, through diode IN4007 and 1k resistor. Q1 switches ON (conduct) and 8V low battery signal is available at cathode used for the following;

- Switch on the low battery indicator LED.
- Give low battery signal to shutdown pin-10 of IC1

The low battery cut-off is as shown in fig. 5

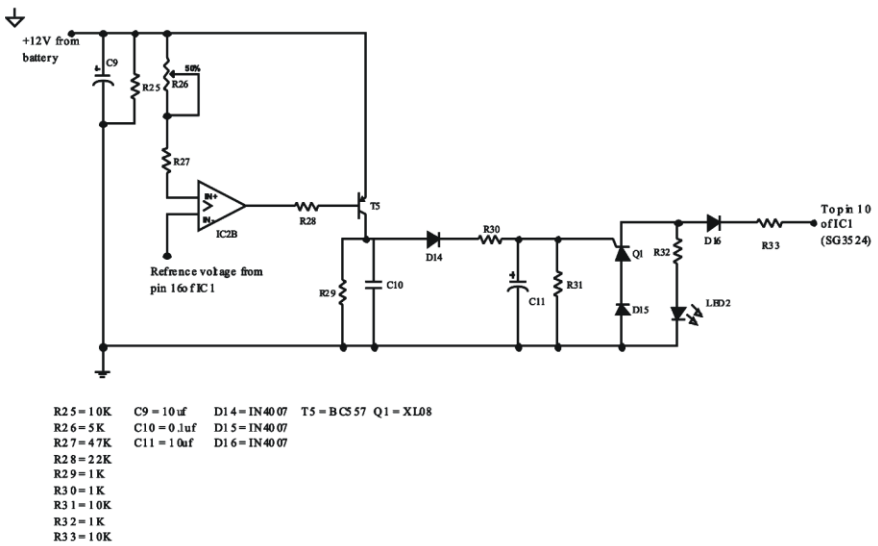

Fig.5. *Low battery cut off circuit diagram*

Battery Charging Control Section

In this mode, the inverter transformer works as a step-down transformer and output 12V at its secondary winding.
During charging, MOSFET at the output section works as rectifier (due to internal diodes), the drain being the cathode and the source as anode. The center tapping of the transformer is connected to the positive terminal of the battery and the MOSFET source is connected to negative terminal of the battery. When the inverter receives AC mains supply, inverter transformer and MOSFET together works as a charger and charge the battery.

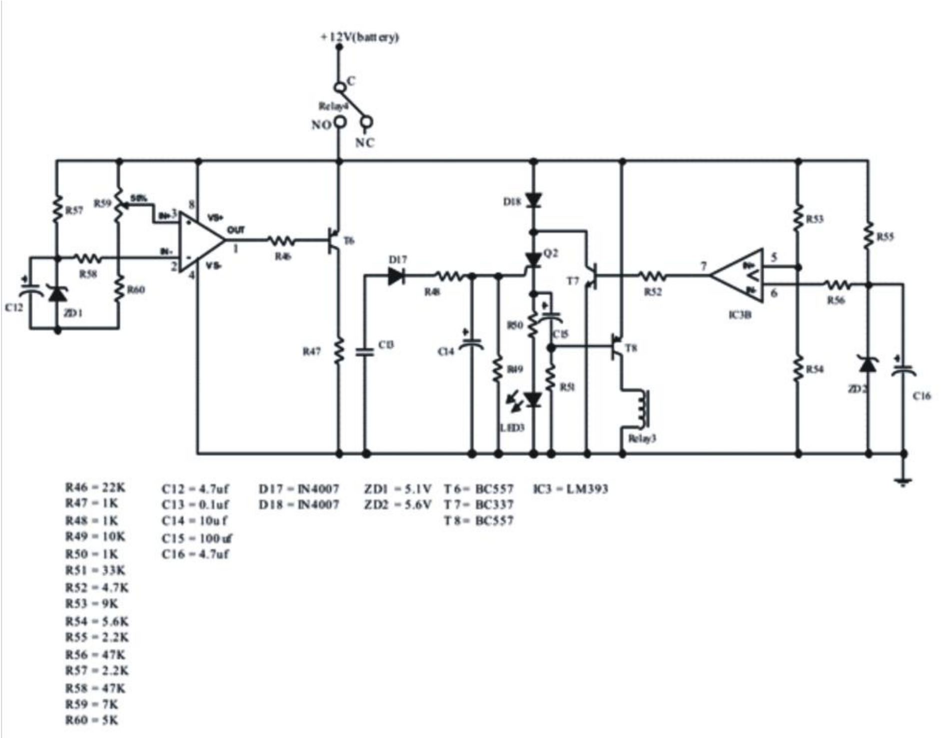

Fig.7. *Battery charging control circuit*

The battery charging control circuit is as shown in fig. 7.

In other to protect the battery from being over charge and the MOSFET from sudden surge current at the start of charging when power is restored, two other circuits are incorporated; the soft start section and charging voltage sensing sections.

13. Charging Voltage Sensing Section

The charging voltage sensing section makes use of Op-Amp A and B of IC3 (LM393), SCR Q2, transistors T6 and T7. Pin-2 and 6 of IC3 is given a constant reference voltage of 5.6V through 47k resistor. Pin-3 is given positive supply from the battery through divider circuit of 5k and 7k resistor.
When the charging battery voltage is below 12V, pin-2 voltage is higher than pin-3 voltage and thus Op-Amp A of IC3 ramps low which biases transistor T6. The voltage at the collector of T6 provides the trigger current I_T for SCR Q2 through 1k resistor. Q2 switches ON (conduct) and 8V battery charging signal is available at cathode used for the following;

- Switch on the charging indicator LED.
- Bias transistor T8 which in-turn turns on the charger relay.

Once Q2 is fired, charging continues until the voltage at pin-5 of IC3 passes a voltage level of 5.6V when the battery is charged beyond 14.5V. At charging battery Volt of 14.5V, pin-5 of IC3 becomes more positive than pin-6 thus op-amp B ramps high to bias transistor T7. The switching of T7 reduces the holding current I_H of Q2 to zero and Q2 stops conducting. Q2 remains in the off state until battery voltage fall below 12V when charging starts again. Charging continues till 14.5V is reached. In this way, the battery charge is topped at interval to keep the battery voltage level before power failure. This is incorporated in fig. 6 battery charging control circuit.

14. Soft Start Section

The soft start section is a charging delay circuit. After a power cut, when the AC supply returns, i.e. when the inverter switch from the battery mode to AC mains mode (i.e. charging mode), the charging process is not started immediately. The charging starts after a small delay of about 6 seconds.

The delay circuit has been incorporated into the charging voltage sensing section. When Q2 starts conducting, 8V is across the capacitor positive terminal. The capacitor charges up to 63.7% before transistor T8 are biased. This takes approximately twice the RC time constant.

Delay time T_d is given by

$$T_d = 2T = 2RC$$

For R = 33K, C = 100µf, $T_d = 6.6s$

$$T_d = 7\text{seconds (approximate value).}$$

This section has being incorporated in fig. 6 battery charging control circuit.

15. Changeover Power Supply Section

The circuit diagram of the changeover power supply circuit for the relays is shown in fig 7**.** The transformer steps the 220Vac voltage down to 12Vac that is rectified by the bridge rectifier and filtered by the 1000µf capacitor. The supply increases to 16V after filtration. The supply is regulated by LM7812 to keep the voltage for relay switching constant at 12V.

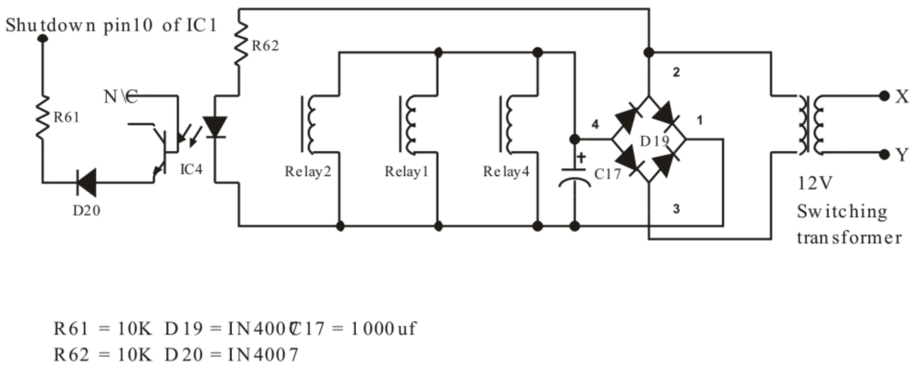

Fig.7. *Power supply circuit for relay switch*

16. Components Selection

T2 – 220V/12V 500mA: The 12V transformer in conjunction with the filter capacitor (1000uf/25V) and regulator (LM7812) guaranteed that 12V was available to switch the relays when the mains voltage is restored.

Full Wave Rectifier: Four diodes, D1 – D4 (IN4007) were used to convert the ac voltage available at the secondary of the power supply circuit to dc. The IN4007 diodes are suitable for the circuit because of its rating (PIV - 1000V, Average Rectified output current for resistive load – 1A, and Non repetitive peak surge current for one cycle – 30A)

Filter Capacitor: the 1000µf /25 capacitor is used to filter the ripple levels present in the rectifier voltage. The values of the capacitor used with a 50Hz supply may range from 100uf – 30,000uf depending on the load current and the degree of smoothening required. In selecting capacitors, the ripple voltage required is 10% of the peak value. The selection of this capacitor is based on the following calculation.

For a charged capacitor Q = CV = It

Thus, $I_L = CV / t$

Thus $C = I_L * t / V_{ripple}$
$t = T = 1/f$
For a full wave rectifier, the frequency of the rectified dc output is 2 x the supply frequency = 100Hz
$T = 1/100 = 0.01s$
V_{ripple} (peak) = $(V_{peak} - V_{d.c})$
$V_{d.c} = V_0$
$V_o = V_{in} \sqrt{2}$
$V_{in} = 24 - V_d$,
V_d being total diode drop = 0.6 * 2 = 1.2
$V_{in} = 12 - 1.2 = 10.8V$
$V_{d.c} = V_0 = V_{in} \sqrt{2}$
$V_{d.c} = V_0 = 10.8 * 1.414 = 15.27V$
$V_{Peak} = 2V_{max}$
Where $V_{max} = 2 V_{r.m.s}$
Therefore,
$2V_m = 2 \times \sqrt{2} \times V_{r.m.s}$
$V_{r.m.s} = 21.6V$
$V_{peak} = 2 \times \sqrt{2} \times 21.6 = 43.20V$
$V_{d.c} = 0.6366 \times V_{peak} = 0.637 \times 61.08 = 27.5V$
$V_{ripple} = V_{peak} - V_{d.c} = 43.20 - 27.5 = 15.7V$
Therefore, $V_{ripple\ (pk-pk)} = 2 \times 15.7 = 31.40V$
10% ripple = 10/100 x 31.40= 3.14V
From $C = I_L * t / V_{ripple}$ with I_L – total load current for four relays = 280mA
C = (0.01s x 0.28A) / 3.14V
C= 891uF (1000uF was used as preferred value)

The working voltage of a filter capacitor must always be more than 1.414 times the expected secondary voltage of the step-down transformer which equals 17V

For this application, 1000uF / 25V is used for C1

17. PERFORMANCE EVALUATION

The inverter was tested on a section by section basis. The output voltage of the oscillator was obtained to be 4.24volts on each side with frequency set to approximately 50Hz. The other unit could not be tested until the final coupling had been done. The battery overcharging protection unit, low battery cut off unit, low and high voltage surge protection as well as the time delay units, feedback unit and the overload and short circuit protection unit were all tested by varying the potentiometer associated with each of them and observing the response through the displays. The list of various settings that were made is listed overleaf;

Table 4.1. *Settings on the Inverter*

Inverter output voltage	220volts
Inverter frequency	50Hz
Minimum battery voltage	10.0volts
Maximum loading capacity	700watts
Minimum A.C. input voltage	180V
Maximum A.C. input voltage	250V

After all the settings were done, the effect of loading was carried out on the INVERTER system and the load test results are as follows.

Table 4.2. *Load Test*

Power (watt)	Voltage (v)

300	225
400	220
500	220
600	220
700	220
800	220
900	0

It was discovered that when the INVERTER was loaded, the output voltage initially to drop and then regulated itself back to 220V. This is due to the feedback action (automatic regulation action) of the IC, SG3524, used as the oscillator.

18. MAINTENANCE, SAFETY AND PRECAUTION

The following maintenance practices and safety precautions are suggested to improve the life span of the system and prevent hazards to the users.

1. Dead batteries should not be used with the inverter
2. The battery terminals should not be removed too often. When it is removed, replacement of correct polarity must be ensured.
3. The inverter must be put in a moderate temperature environment.
4. The inverter should always be shut down when not in use
5. The inverter should always be partially loaded (not more than 80% of its maximum capacity will be enough).
6. The use if inductive loads like refrigerator, induction machine e.t.c. on the inverter should be avoided.
7. The input plug of the inverter should be plugged to a three-pin, properly earthed socked.

19. CONCLUSION

The construction of 1kVA inverter with control circuits is a novel design for optimum performance. The overload and battery short down is another control circuit to protect the inverter system from being damaged and to extend the life-span of the battery in use. The monitoring circuit incorporated into the inverter system is another good ideal for non-professional to know the state of the system at a glance.

REFERENCES

[1] Theraja, B.L. and Theraja, A.K. (1999). Textbook of Electrical Technology. (Twenty-Second Edition). Prentice Hall Inc.

[2] Lander, C.W. (1999). Power Electronics (Second Edition). S Chad & Company.

[3] Boylestad, R.L. and Nashelsky, L. (1999). Electronics Devices and Circuit Theory (Seventh Edition). Prentices Hall Inc.

[4] Rasheed, M. (1992). Power Electronics, Circuits, Device and Application (Second Edition). Prentice Hall Inc.

[5] Forrest, M. (2000) .Getting Started In Electronics (2nd Edition).

[6] Oni, J.O.(2005). Fundamentals of Power Systems Protection.

[7] Mgottlieb, I. (1985). Power switching Regulator Inverters and Converters (1st Edition). Tab Book Inc.

[8] Usifo, O. (2002) Fundamentals of Electro–mechanical Devices and Machines. Fredorus Ltd

[9] www.DonRowe.com

[10] www.datasheetcatalog .com