

TRAINING PROGRAMME
ON

SALIENT FEATURES OF SERVICE MANUAL

DECEMBER 2008 - 09

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1) INTRODUCTION OF INVERTER & UPS

1.0 An OVERVIEW

The UPS is a high power enhanced line interactive uninterruptible power source which provides clean, reliable AC power to systems like computer, data handling & telecommunication loads. Normally the UPS operates “on-line” and provides power derived from the input main source, continuously regulating the load voltage to compensate for voltage fluctuations on the mains. A multilevel transformer tap changing circuit provides this regulation while attaining high levels of on-line efficiency. To adjust the load voltage, the UPS temporarily operates the load from battery power while an appropriate transformer tap change is made. If line condition becomes unacceptable, the UPS transfers load power from the mains to the inverter (on-battery operation) synchronously and virtually seamlessly under all conditions. The voltage waveshape during on-battery operation is a low distortion sine wave. Resynchronization and transfer of load power back to the mains is automatic when the line voltage is again within normal limits.

A complete UPS system consists of three module types: an Electronic Unit (EU) mounted on top of an Isolation Unit (IU) and Battery Packs, which can be added to increase on-battery run time. The EU self connects to the IU when mounted, and contains the UPS’s micro-processor controls, inverter, battery charger, transfer and tap changing circuits, remote interfaces, user controls and the display panel. The IU contains the UPS’s isolation transformer, EMI/ RFI filtering & surge suppression circuits, by-pass circuit, the mains & the load wiring interfaces. The Battery Packs “daisy chain” from the EU using a heavy duty cable and lockable connector system. The Battery Packs and the EU communicate over modular plug cables. Each Battery Pack contains four high capacity batteries and microprocessor controlled electronics for communications and battery pack monitoring.

HOT SWAPPABLE MODULES

The IU is capable of autonomous operation and allows service or upgrade of the Electronics Unit (EU) without interruption of power to the load. In addition, a worn Battery Pack can be replaced, or new packs can be added, while maintaining power to the load. In the event of EU failure, functions controlled by the EU are automatically by passed and the IU operates autonomously. For servicing, this by pass mode may be selected manually.

EMERGENCY POWER OFF

For applications where, for safety reasons, power to all room equipment may be cut off, the UPS provides a remote Emergency Power Off interface.

DISPLAY

Local UPS user interface is served by a display and control panel containing a back lit 2 x 16 character display and three buttons. Using the buttons, menus for displaying UPS status, UPS control commands, UPS setup, UPS tests & UPS

diagnostics are shown. Critical UPS functions can be password protected. A loud audible alarm warns of operating modes that could result in the loss of power to the load without user intervention.

REMOTE INTERFACES

The UPS provides a full of RS 232 communication computer interface. When used with Power Doctor UPS monitoring software and a serially connected local DOS PC, the local display and control panel functions are duplicated and power quality events can be logged.

1.1 INVERTER

Inverter convert battery DC Power into AC Power

Inverter converts the battery power current into conventional A/C power. This power can be used to run almost any AC appliance absolutely anywhere. They can run items such as mobile phone chargers, lights, electrical appliances, power tools, computers, faxes, TV sets, microwave ovens, battery chargers & motors.

SINE WAVE INVERTERS

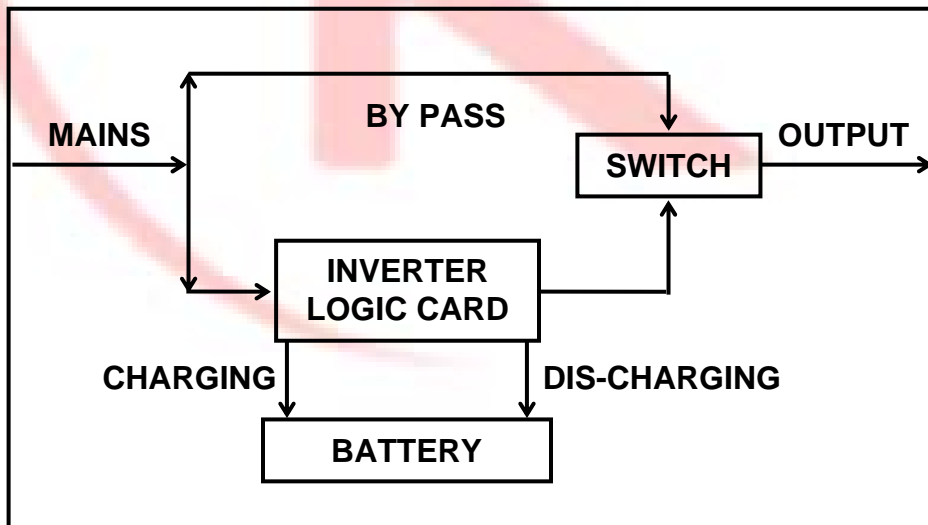
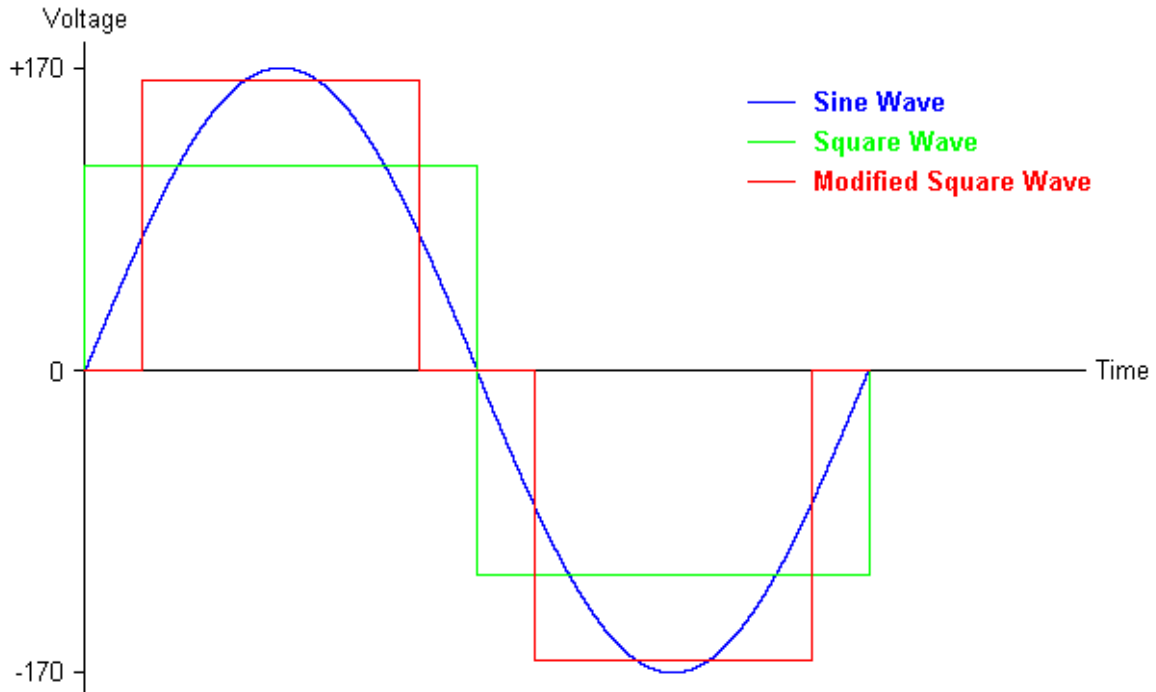
The use of sine wave inverters has increased significantly in the last few years. The basic principle employed in sine wave power inverters lies in the conversion of AC (Alternate Current) power to DC (Direct Current) power. This is helpful in emergency situations where there is a need to run electrical equipment. It is a simple, convenient and finds its use mostly on mobile applications like boats & RV's. Sine wave inverters are often manufactured in the shape of small rectangles that consists of jack along with a trailing wire. It can be inserted directly on the dashboard or even plugged into cigarette lighter. Connections to the battery could be given directly with the help of the jumper like cables.

The device contains outlets, probably one or two, for electrical cords that are standard. For RV parks, where there is lack of electricity, sine wave power inverters play a major role to power everyday household appliances. Sine wave power inverters can be used even in a digital movie camera so that pictures could be taken without any interruption even though the battery goes down.

There are different models of sine wave power inverters available depending upon the wattage needed. The total wattage required is directly proportional to the total draw of the appliance that is being used. Wave output in power inverters can be classified into three different types such as:

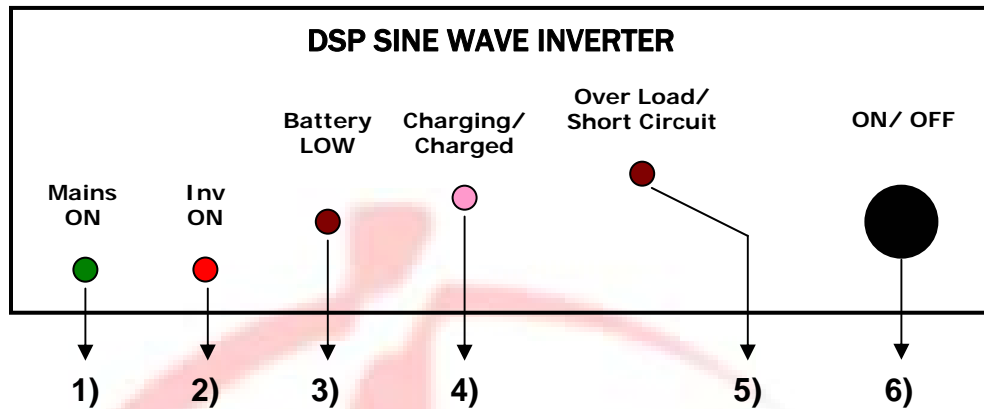
- a. **SQUARE WAVE INVERTER** - The square wave is the simplest and the least expensive type, but now days it is practically not use because of low quality of power.
- b. **PURE SINE WAVE/ TRUE SINE WAVE INVERTER** - Pure sine wave inverters produce AC voltage with low total harmonic distortion (typically below 3%). They are used when there is a need for clean sine wave output for some sensitive devices such as medical equipment laser printers stereos etc.

c. **MODIFIED SINE WAVE INVERTER** - The modified sine wave topologies (which are actually modified square wave) produce square wave with some dead spots between positive & negative half-cycles. They are suitable for many electronic loads & are the most popular low-cost inverter on the market today.



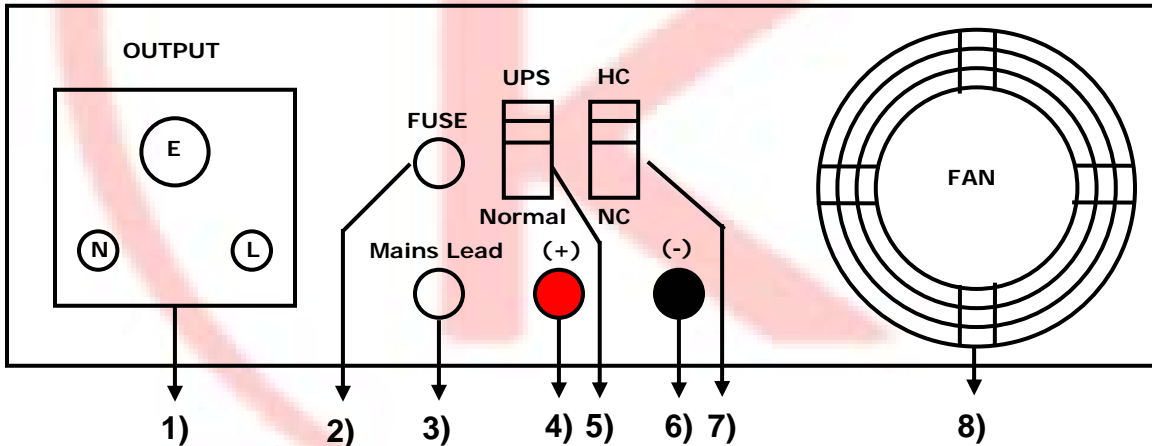
System Detail: 600/800/1400VA HOME UPS

Front Panel Detail:



- 1) Green light on indicating the AC input/mains.
- 2) Yellow light on indicating that inverter running on battery.
- 3) This light on indicating that battery low.
- 4) If this light blink that means battery in charging& continuous glow indicating Battery charged.
- 5) Red light on indicating the home ups is under over load/short circuit on out put.
- 6) Inverter on off switch.

Rear Panel Detail:



- 1) Out put socket.
- 2) Out put fuse.
- 3) Mains input 3 core wire
- 4) Battery positive wire
- 5) Selector switch ups/normal mode
- 6) Battery negative wire
- 7) Selectors switch high charging/normal charging.
- 8) Fan for cooling.

Status LED Display:

Status	LED Display	Color	Alarm
Present Utility	Mains on Charging/ Charged	Green Green (blinking/continuous)	No No
AC Input Fail	Inverter on	Yellow	Every 5 min. in ups mode
Low Battery	Battery low	Red	Continuous beep
Over load/ Short Circuit	Over load/ Short Circuit	Red	Continues beep
Fuse Blow	Mains light blinking	Green	Continuous beep

1.2 UPS

Survey indicates that 50% of the malfunctioning that happened during data processing was caused by commercial power disturbance. This explains the importance of configuration of a UPS together with a Computer system, telecommunications, medical instrument, process control, security system, CNC machine and all power sensitive equipment. The UPS is designed to protect computer, telecommunication, medical instrument, process control, security system, CNC machine and all power sensitive equipment against any power failure or disturbance.

There are three different types of UPS that are suitable for different tasks and supporting different types of load. These are:

- b. Off-Line Stand by
- c. Line Interactive
- d. On-Line Double Conversion
- a. Off-Line Stand by

During normal operation, the power flows straight through the unit and hence only RFI filtering is usually provided. When the input voltage fails or fluctuates outside of a pre-set tolerance window, the UPS detects this and a relay will close allowing the UPS to start feeding battery power via the inverter.

b. Line Interactive

A line interactive UPS operates in a very similar fashion to an off-line UPS, except with the advantage of better filtering and output voltage boost/ reduce features. Whilst not eliminating mains borne interference, line interactive

Block diagram of off-line UPS is as follows:

Block diagram of inverter is as under:

3) WIRING DIAGRAM OF INVERTER & UPS

Wiring diagrams of inverters of various capacity are given as under:

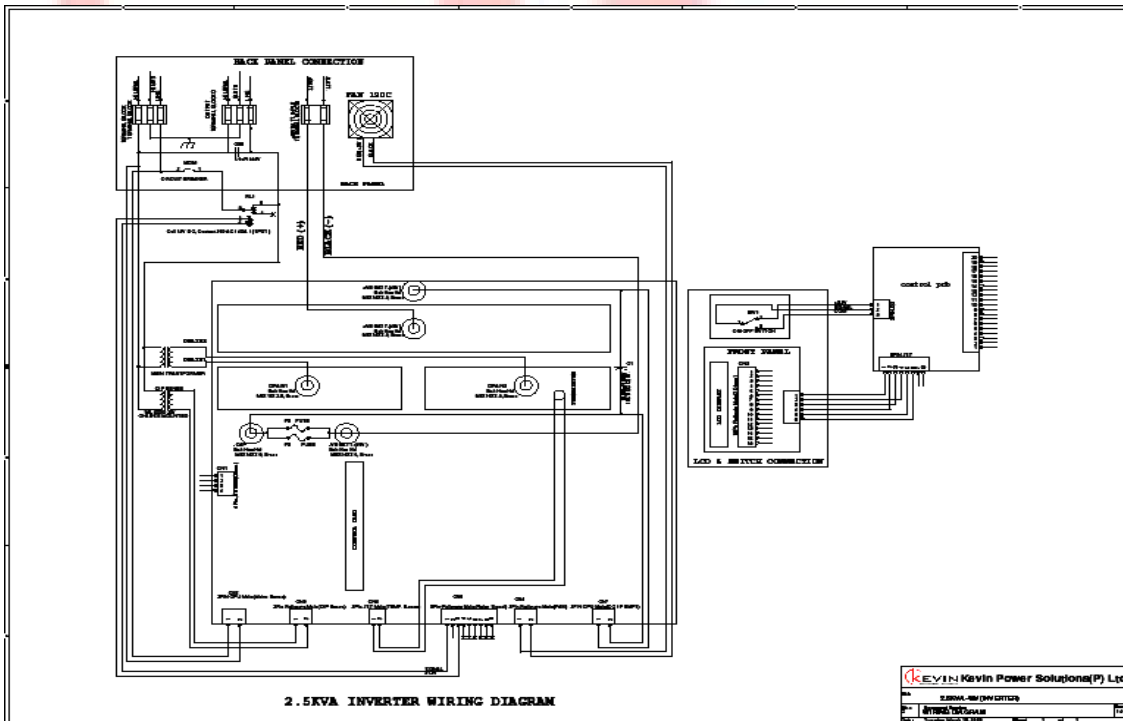
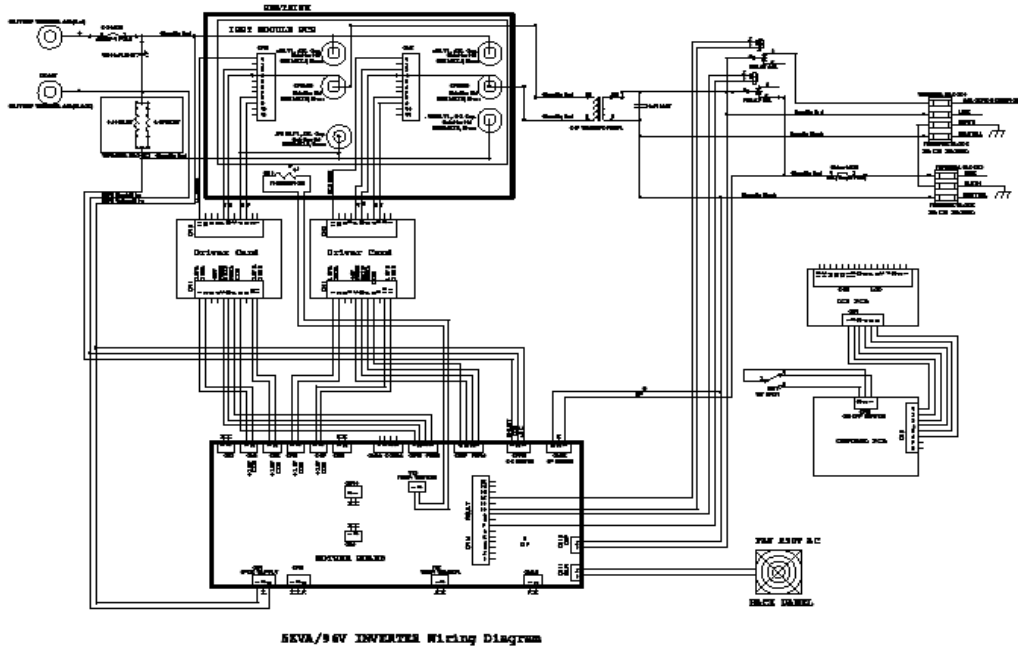
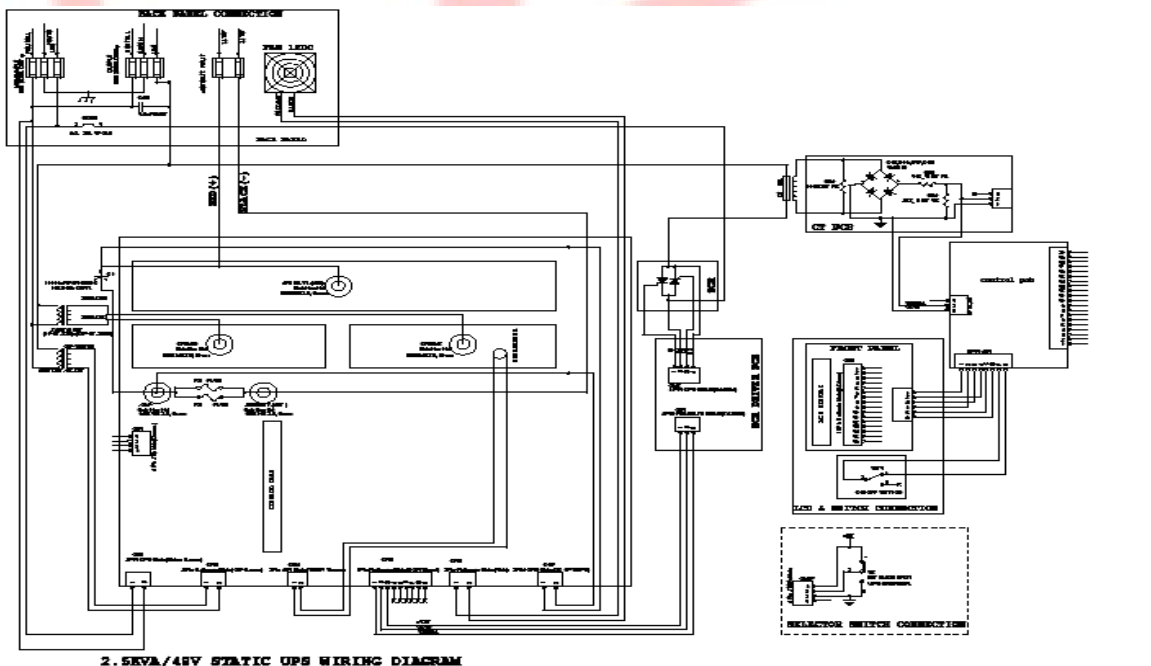


Fig. 1. Wiring diagram of 2.5 KVA/ 48 V Inverter



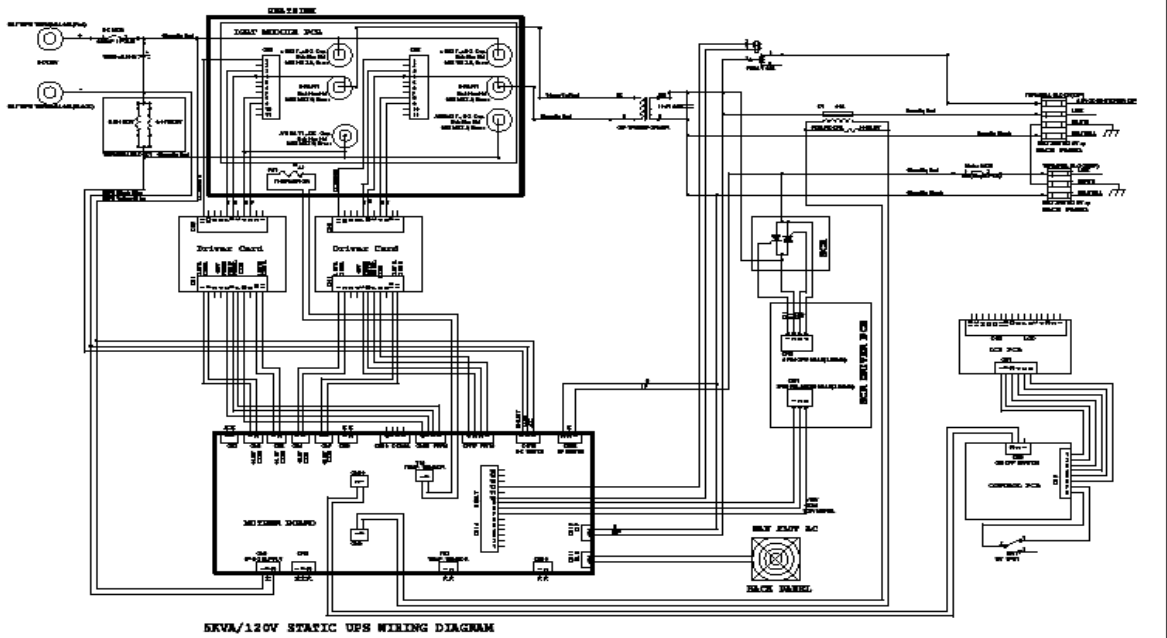
KEVIN Kevin Power Solutions(P) Ltd
 200A, 20th FLOOR, 20th FLOOR
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Fig. 2 Wiring diagram of 5 KVA/ 96 V inverter



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Fig. 3 Wiring diagram of 2.5 KVA/ 48 V Static UPS




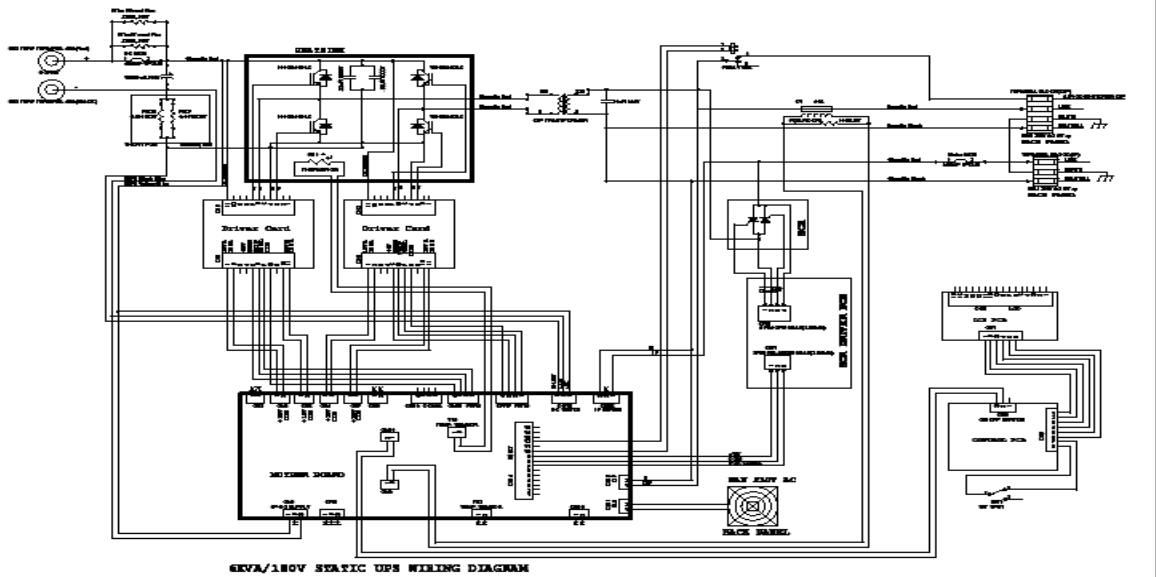

 No. 88/4, SEMENTATI LANE
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 Tel: 6342 2222, 6342 2223 Fax: 6342 2224

Fig. 4 Wiring diagram of 5 KVA 120 V Static UPS





 No. 88/4, SEMENTATI LANE
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Fig. 5 Wiring diagram of 6 KVA/ 180 V Static UPS

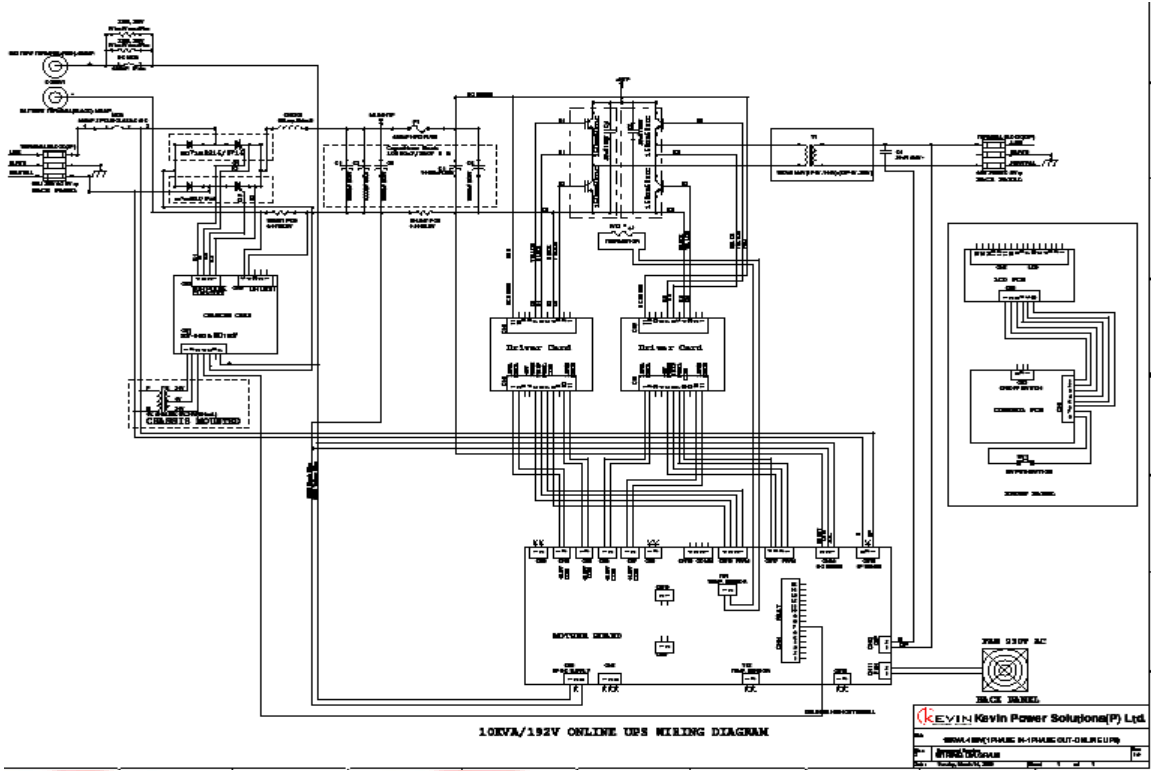


Fig. 8 Wiring diagram of 10 KVA/ 192 V On-Line UPS

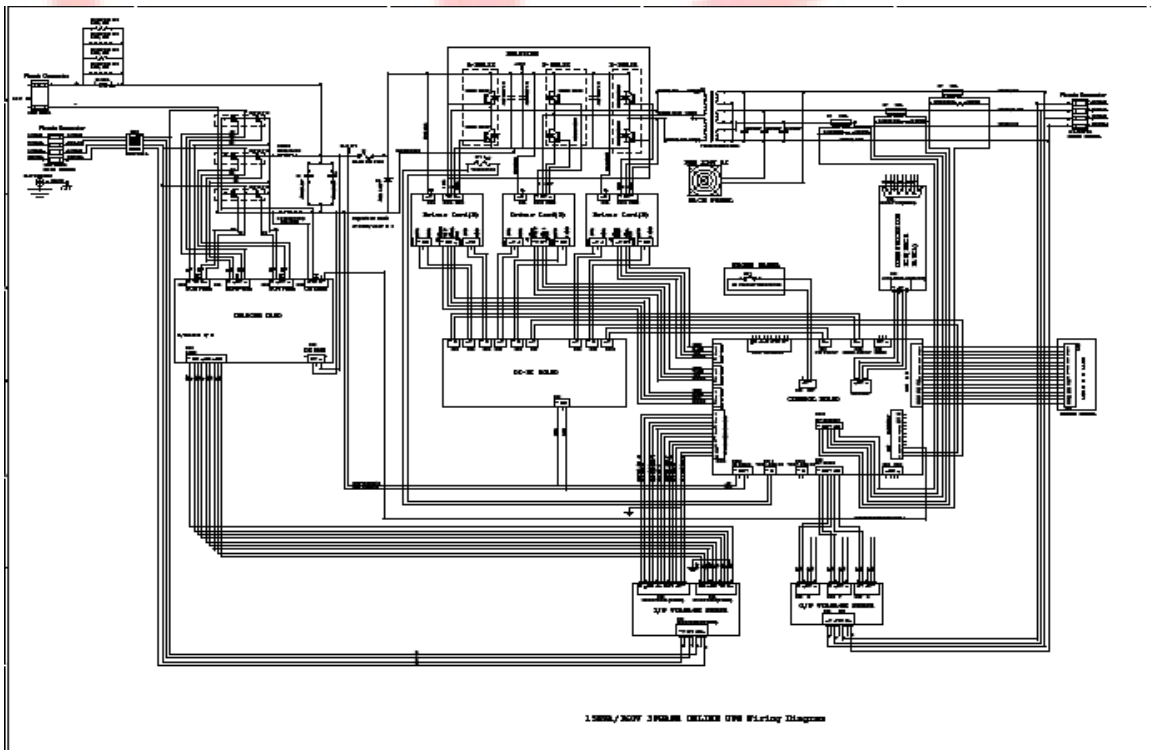


Fig. 9 Wiring diagram of 15 KVA/ 360 V 3 Phase-in; 3 Phase-out On-Line UPS

4) CIRCUIT DIAGRAM OF INVERTER



5) TESTING PROCEDURE

◀ TESTING PROCEDURE

(Online)

STEPS:

- Visual inspection of the system.
- Check all connections; they must be in proper way and proper position.
- Check all joints, they must be tight.
- Check all MCBs & switch OFF zig & the system must be OFF.
- Connect system with zig properly.
- By pass the IGBT (system).(By removing Fuse & wire(between choke and DC capacitor))
- Then remove connection of the port CN1, CN2, CN3 of charger card and port CN1, CN16, CN15 of mother card.
- Put the mains MCB (Zig) ON and then put mains MCB of the system, then check the voltage on blue wires of 6-pin female connector (black wire is ground) it must be 15V.
- Now OFF all MCB's and put the connection of CN1 port.
- Now put the CRO's ground probe on the heat sink of IC1 and main lead body of the Q1 and check the amplitude of pulse it must be 2.5v and see the formation of the teeth; it must be very smooth.
- Then with the same process as above done check Q2, voltage must be 15v and frequency must be up to 1 kHz.
- Now check voltage on port CN3 it must be 15v.
- Now check port CN2, it having 4pins; from right to left 1st pin is ground put CRO ground probe to 1st pin and check 2nd pin it will show sine wave now on 3rd pin it will show spicks and 4th pin will show it's modulation.
- Now connect the connector CN2&CN3, and check smooth DC formation.
- Make choke to DC capacitor wire connection.
- Now putt all connections of charger card and mother card except CN1.
- Now make DC by using pot P1 (variable resistance) as per specification.
- Now OFF all MCBs and put the connection CN1.
- Check IGBT Driver card by checking PWM on MOSFET one by one. It must be 15v.
- Now charge DC capacitor on IGBT and ON the system and check the fan. (If it's moving then OK) and also check O/P sine waveform on CRO.
- Now OFF the AC MCB and connect Fuse.
- Now ON AC MCB and check the fan; if it's running then OK and if it shows SHORT CIRCUIT then check the IGBT driver.
- Put the communication wire into the mother board.
- Now open testing tool (communication) in computer.

- Now check the LCD and Parameters and also O/P waveform.(it must be pure sine wave)

◀STATIC UPS TESTING PROCEDURE **(2.5/3/3.5 KVA)**

STEPS:

- Visual inspection of the system.
- Check all connections; they must be in proper way and proper position.
- Check all joints, they must be tight.
- Check all MCBs & switch OFF zig & the system must be OFF.
- Connect system with zig properly.
- Then ON the battery MCB of zig.
- Check DC supply of the Mother card.
- Put the communication wire into the mother board.
- Now open testing tool (communication) in computer and tune battery voltage as per the system specification.
- Now check the LCD and Parameters.
- Switch ON inverter switch. (from the front panel of the system)
- Check LCD; inv switch must be OK.
- Then check O/P voltage & tune it.
- Check O/P frequency; it must be 50Hz & wave form on CRO.
- Now put the load of 60% & check fan.
- If it's OK then put the load 100% & tune.
- Apply the short ckt. Test.
- Now reduce the load and apply Mains from the zig.
- System will show **Mains MCB Trip**.
- Then ON Mains MCB & tune mains voltage according to I/P voltage.
- Then tune Charging current as per instruction.
- Tune CT current as per instructions.
- OFF Mains & Battery MCB of the system and zig.
- Remove communication and connect normal/ups connector.
- ON battery MCB put 100% load.
- Check UPS/Inv.switch on display then apply Mains ON.
- Check voltage & zero crossing. If OK then system OK; if not OK then interchange the drain wires & then again check zero crossing. If all is right then system is done.

◀ TESTING PROCEDURE

Kva For higher

STEPS:

- Visual inspection of the system.
- Check all connections; they must be in proper way and proper position.
- Check all joints, they must be tight.
- Check all MCBs & switch OFF zig & the system must be OFF.
- Connect system with zig properly.
- By pass the IGBT (system).(By removing DC CAPACITOR)
- Then ON the battery MCB of zig.
- Check IGBT Driver card by checking PWM on MOSFET one by one. It must be 15v.
- Now charge DC capacitor on IGBT and ON the system and check the fan. (If it's moving then OK) and also check O/P sine waveform on CRO.
- Now OFF the DC MCB and connect DC CAPACITOR.
- Now ON battery MCB and check the fan; if it's running then OK and if it shows SHORT CIRCUIT then check the IGBT driver.
- Put the communication wire into the mother board.
- Now open testing tool (communication) in computer and tune battery voltage as per the system specification.
- Now check the LCD and Parameters and also O/P waveform.
- Switch ON inverter switch. (from the panel of the system)
- Check LCD; inv switch must be OK.
- Then check O/P voltage & tune it in between 220 to 230.
- Check O/P frequency; it must be 50Hz & wave form on CRO.
- Now put the load of 60% & check fan.
- If it's OK then put the load 100% & tune.
- Apply the short ckt. Test.
- Now reduce the load and apply Mains from the zig.(mains must be 230v)
- System will show **Mains MCB Trip**.
- Then ON Mains MCB & tune mains voltage according to I/P voltage.
- Then tune Charging current as per instruction.
- Tune CT current as per instructions.
- OFF Mains & Battery MCB of the system and zig.
- Remove communication and connect normal/ups connector.
- ON battery MCB put 100% load.
- Check UPS/Inv.switch on display then apply Mains ON. Check voltage & zero crossing. If OK then system OK; if not OK then interchange the drain wires & then again check zero crossing. If all is right then system is done.

◀ TESTING PROCEDURE

(3-PHASE INVERTER/LUPS)

STEPS:

- Visual inspection of the system.
- Check all connections; they must be in proper way and proper position.
- Check all joints, they must be tight.
- Check all MCBs & switch OFF zig & the system must be OFF.
- Connect system with zig properly.
- By pass the IGBT (system).(By removing +ve(red) terminal of DC CAPACITOR)
- Remove all connection from DC-DC card.
- Then ON the battery MCB of zig.
- Now check the voltage at the CN1 female port it must be same as I/P DC supply.
- Now off the DC MCB and connect the female connector to the male CN1 port.
- Now ON DC MCB and check voltage at the port CN3 to CN10, it must be 15v and at port CN7, voltage should be 5v.
- Now OFF DC MCB & connect all connection of DC-DC card.
- Now ON DC MCB of zig as well as system.
- Check IGBT Driver card by checking PWM on MOSFET one by one. It must be 15v.
- Now charge DC capacitor on IGBT and ON the system and check the fan. (If it's moving then OK) and also check O/P sine waveform on CRO.
- Apply the short ckt.Test.
- Now OFF the DC MCB and connect DC CAPACITOR.
- Now ON battery MCB and check the fan; if it's running then OK and if it shows SHORT CIRCUIT then check the IGBT driver.
- Now match DC by using preset (variable resistance) in control card, it must be same as DC I/P supply (on LCD).
- Now check the sequence of O/P voltage by using Sequence Meter.
- Now check the LCD and Parameters and also O/P waveform.
- Switch ON inverter switch. (from the panel of the system)
- Check LCD; inv switch must be OK.
- Then check O/P voltage & tune it in between 220 to 230,by using preset on control card.(PN)
- Check O/P frequency; it must be 50Hz & wave form on CRO.
- Now put the load of 60% & check fan.
- If it's OK then put the load 100% & tune it as pre specification by using preset placed on Control card.

6) AULT FINDING OF INVERTER



7) INSTALLATION PROCEDURE & PRECAUTIONS

7.1 Installation Procedures

Inverter/ Static UPS are sophisticated devices and must be treated accordingly. Keep the inverter/ static UPS in non-condensing, well ventilated environment, ensuring that there are no ingresses of moisture or foreign material. Inverter/ Static UPS should be kept as close as possible to the battery in order to keep the battery cables short. However, do not locate the inverter/ static UPS in the same compartment as non-sealed batteries. Batteries generate gases, which are very corrosive to electrical equipment and everything else.

Operation

Once the AC & DC wiring have been installed and connected, take a moment to re-examine all the connections and make sure they are secured and in the proper terminals. Check to see that the inverter/ static UPS are turned off, and then apply battery DC power to it. Ensure that all wiring has been installed properly. Turn on the battery bank DC disconnect or connect the proper Fuse/ MCB in line to the battery to complete the battery circuit. Put ON/ OFF switch to the ON position. The inverter/ static UPS should run a load without AC input (battery only). Place a load on the inverter/ static UPS and make sure that it works. To change the batteries, connect AC power to the inverter/ static UPS by plugging in the AC power and turning on the MAIN line. This shows that charger is working properly. Any AC load powered by the inverter/ static UPS should also work at this point since a protection of the AC power is passed through the inverter/ static UPS to power the loads. The delay before connecting is provided within acceptable frequency and voltage limits. Disconnect the AC power. The inverter/ static UPS should transfer to inverter/ static UPS mode immediately. This will be indicated by a clicking sound as the internal transfer relay changes position. The inverter/ static UPS will begin to take power from the batteries and use it to power the load and the load continues to operate uninterrupted.

- 1) Make sure that the MCB's on the rear panel are OFF
- 2) Connect in-put mains wires according to the indication of (N-L-E)/ (R-Y-B) on the terminals block
- 3) Connect out-put wires according to the indication of (N-L-E)/ (R-Y-B-N) on the terminal block
- 4) Ready battery bank as on-line UPS battery voltage rating. Connect battery positive and negative wires in inverter/ UPS according to the indication on rear panel.

7.2 Precautions

General Precautions:

Please read the general precautions carefully:

- ✚ Before using the Three Sixty DSP Sine Wave Inverter/ Static UPS, read all the instructions and caution marking on the inverter/ static UPS, the batteries, all appropriate sections of this Instruction Manual.
- ✚ Do not expose Three Sixty DSP Sine Wave Inverter/ Static UPS to any type of chemicals
- ✚ Do not assemble the Three Sixty DSP Sine Wave Inverter/ Static UPS. Take it to a qualified Three Sixty Engineering Service Centre when service or repair is required. Opening by unqualified person can lead electrical shock or fire hazard
- ✚ To reduce risks of electrical shock, disconnect all wiring before cleaning
- ✚ **Warning:** Avoid exposing the inverter/ static UPS or batteries to any type of explosive gases (in the vicinity, as batteries generate explosive gases during normal operation), provide ventilation to outdoors from the battery compartments. The battery enclosures should be designed to prevent accumulation and concentration by hydrogen gas in “POCKET” at the top of the compartment. Vent the battery compartment from the highest point. A sloped lid can also be used to direct the flow to the vent opening location. To reduce the risk or the battery explosion, follow all the instruction of battery supplier or any equipment you intend to use in the vicinity of the batteries
- ✚ Use the correct tools to make AC/ DC wiring connections
- ✚ Do not install this Three Sixty DSP Sine Wave Inverter/ Static UPS on or near flammable materials like plywood, chemicals, gasoline etc.)

CAUTION: *The Three Sixty DSP Sine Wave Inverter/ Static UPS should be connected to grounded, permanent wiring systems*

Personal Precautions

- ✚ Someone should be within the range of your voice to come to you aid when you work near batteries
- ✚ Keep plenty of fresh water and soap nearby in the event that battery acid contact skin, clothing or eyes

Wear complete eye protection and clothing protection

- ✚ Avoid touching eyes while working near batteries; wash your hands with soap, when done
- ✚ If battery acid comes in contact with skin or clothing, wash immediately with soap and water. If acid enters eyes, immediately flood eyes with running cool water for at least 15 minutes and get medical attention immediately
- ✚ Baking soda neutralizes battery electrolyte. Keep a supply in the battery area handy.
- ✚ NEVER smoke or allow spark or a flame in the vicinity of the battery
- ✚ Be extra cautious when working with metal tools on and around batteries. It could short circuit the batteries or other electrical parts producing a spark that could cause an explosion
- ✚ Remove personal metal items such as rings, bracelet, necklace and watches when working with the battery. Battery can produce a short circuit current high enough to cause severe burns
- ✚ Never attempt to charge a frozen battery
- ✚ Before touching the battery terminal make sure that the inverter/ static UPS front switch is OFF and AC mains to the inverter/ static UPS is also OFF
- ✚ If it is necessary to remove any battery, always remove the grounded terminal from the battery first. Make sure that all the accessories are OFF, so as not to cause arcing
- ✚ Be sure that the area around the battery is well ventilated
- ✚ Clean battery terminals. Be careful not to allow corrosion to come in contact with the eyes
- ✚ Study all the battery manufacturer's specific precautions and recommended rates of charge.
- ✚ Add only distilled water in each cell until battery acid reaches level specified by battery manufacturer. This helps purge excessive gas from cells. Do not overfill. For a battery without caps carefully follow manufacturer's recharging instructions



High Frequency Home UPS

An **inverter** is an electrical or electro-mechanical device that converts [direct current](#) (DC) to [alternating current](#) (AC); the resulting AC can be at any required voltage and frequency with the use of appropriate [transformers](#), switching, and control circuits.

Static inverters have no moving parts and are used in a wide range of applications, from small [switching power supplies](#) in computers, to large [electric utility high-voltage direct current](#) applications that transport bulk power. Inverters are commonly used to supply AC power from DC sources such as [solar panels](#) or [batteries](#).

The electrical inverter is a high-power [electronic oscillator](#). It is so named because early mechanical AC to DC converters were made to work in reverse, and thus were "inverted", to convert DC to AC. The inverter performs the opposite function of a [rectifier](#).

DC power source utilization



Inverter designed to provide 115 VAC from the 12 VDC source provided in an automobile. The unit shown provides upto 1.2 Amps of alternating current, or just enough to power two sixty watt light bulbs.

An inverter converts the DC electricity from sources such as [batteries](#), [solar panels](#), or [fuel cells](#) to AC electricity. The electricity can be at any required voltage; in particular it can operate AC equipment designed for mains operation, or rectified to produce DC at any desired voltage.

[Grid tie inverters](#) can feed energy back into the distribution network because they produce alternating current with the same wave shape and frequency as supplied by the distribution system. They can also switch off automatically in the event of a [blackout](#).

Micro-inverters convert direct current from individual solar panels into alternating current for the electric grid ^[1].

[edit] Uninterruptible power supplies

An [uninterruptible power supply](#) is a device which supplies the stored electrical power to the load in case of raw power cut-off or blackout. One type of UPS uses batteries to store power and an inverter to supply AC power from the batteries when main power is not available. When main power is restored, a rectifier is used to supply DC power to recharge the batteries.

[edit] Induction heating

Inverters convert low frequency main AC power to a higher frequency for use in [induction heating](#). To do this, AC power is first [rectified](#) to provide DC power. The inverter then changes the DC power to high frequency AC power.

[edit] HVDC power transmission

With [HVDC](#) power transmission, AC power is rectified and high voltage DC power is transmitted to another location. At the receiving location, an inverter in a [static inverter plant](#) converts the power back to AC.

[edit] Variable-frequency drives

Main article: [variable-frequency drive](#)

A [variable-frequency drive](#) controls the operating speed of an AC motor by controlling the frequency and voltage of the power supplied to the motor. An inverter provides the controlled power. In most cases, the variable-frequency drive includes a [rectifier](#) so that DC power for the inverter can be provided from main AC power. Since an inverter is the key component, variable-frequency drives are sometimes called inverter drives or just inverters.

[edit] Electric vehicle drives

Adjustable speed motor control inverters are currently used to power the [traction motor](#) in some [electric locomotives](#) and [diesel-electric](#) locomotives as well as some [battery electric vehicles](#) and [hybrid electric](#) highway vehicles such as the [Toyota Prius](#). Various improvements in inverter technology are being developed specifically for electric vehicle applications.^[2] In vehicles with [regenerative braking](#), the inverter also takes power from the motor (now acting as a generator) and stores it in the batteries.

[\[edit\]](#) The general case

A [transformer](#) allows AC power to be converted to any desired voltage, but at the same frequency. Inverters, plus rectifiers for DC, can be designed to convert from any voltage, AC or DC, to any other voltage, also AC or DC, at any desired frequency. The output power can never exceed the input power, but efficiencies can be high, with a small proportion of the power dissipated as waste heat.

[\[edit\]](#) Circuit description

Top: Simple inverter circuit shown with an [electromechanical switch and automatic equivalent](#) auto-switching device implemented with two transistors and split winding auto-transformer in place of the mechanical switch.

Square waveform with fundamental sine wave component, 3rd harmonic and 5th harmonic

[\[edit\]](#) Basic designs

In one simple inverter circuit, DC power is connected to a [transformer](#) through the centre tap of the primary winding.. A switch is rapidly switched back and forth to allow current to flow back to the DC source following two alternate paths through one end of the primary winding and then the other. The alternation of the direction of current in the primary winding of the transformer produces [alternating current](#) (AC) in the secondary circuit.

The electromechanical version of the switching device includes two stationary contacts and a spring supported moving contact. The spring holds the movable contact against one of the stationary contacts and an electromagnet pulls the movable contact to the opposite stationary contact. The current in the electromagnet is interrupted by the action of the switch so that the switch continually switches rapidly back and forth. This type of electromechanical inverter switch, called a [vibrator](#) or buzzer, was once used in [vacuum tube](#) automobile radios. A similar mechanism has been used in door bells, buzzers and [tattoo guns](#).

As they have become available, [transistors](#) and various other types of [semiconductor](#) switches have been incorporated into inverter circuit designs.

[\[edit\]](#) Output waveforms

The switch in the simple inverter described above produces a square voltage [waveform](#) as opposed to the [sinusoidal](#) waveform that is the usual waveform of an AC power supply. Using [Fourier analysis](#), [periodic](#) waveforms are represented as the sum of an infinite series of sine waves. The sine wave that has the same [frequency](#) as the original waveform is called the fundamental component. The other sine waves, called *harmonics*, that are included in the series have frequencies that are integral multiples of the fundamental frequency.

The quality of the inverter output waveform can be expressed by using the Fourier analysis data to calculate the [total harmonic distortion](#) (THD). The total harmonic distortion is the square root of the sum of the squares of the harmonic voltages divided by the fundamental voltage:

The quality of output waveform that is needed from an inverter depends on the characteristics of the connected load. Some loads need a nearly perfect sine wave voltage supply in order to work properly. Other loads may work quite well with a square wave voltage.

[\[edit\]](#) Advanced designs

[H-bridge](#) inverter circuit with transistor switches and antiparallel diodes

There are many different power circuit [topologies](#) and [control strategies](#) used in inverter designs. Different design approaches address various issues that may be more or less important depending on the way that the inverter is intended to be used.

The issue of waveform quality can be addressed in many ways. [Capacitors](#) and [inductors](#) can be used to [filter](#) the waveform. If the design includes a transformer, filtering can be applied to the primary or the secondary side of the transformer or to both sides. [Low-pass filters](#) are applied to allow the fundamental component of the waveform to pass to the output while limiting the passage of the harmonic components. If the inverter is designed to provide power at a fixed frequency, a [resonant](#) filter can be used. For an adjustable frequency inverter, the filter must be tuned to a frequency that is above the maximum fundamental frequency.

Since most loads contain inductance, feedback [rectifiers](#) or [antiparallel diodes](#) are often connected across each [semiconductor](#) switch to provide a path for the peak inductive load current when the switch is turned off. The antiparallel diodes are somewhat similar to the [freewheeling diodes](#) used in AC/DC converter circuits.

Fourier analysis reveals that a waveform, like a square wave, that is antisymmetrical about the 180 degree point contains only odd harmonics, the 3rd, 5th, 7th etc. Waveforms

that have steps of certain widths and heights eliminate or “cancel” additional harmonics. For example, by inserting a zero-voltage step between the positive and negative sections of the square-wave, all of the harmonics that are divisible by three can be eliminated. That leaves only the 5th, 7th, 11th, 13th etc. The required width of the steps is one third of the period for each of the positive and negative voltage steps and one sixth of the period for each of the zero-voltage steps.

Changing the square wave as described above is an example of [pulse-width modulation](#) (PWM). Modulating, or regulating the width of a square-wave pulse is often used as a method of regulating or adjusting an inverter's output voltage. When voltage control is not required, a fixed pulse width can be selected to reduce or eliminate selected harmonics. Harmonic elimination techniques are generally applied to the lowest harmonics because filtering is more effective at high frequencies than at low frequencies. *Multiple pulse-width* or *carrier based* PWM control schemes produce waveforms that are composed of many narrow pulses. The frequency represented by the number of narrow pulses per second is called the *switching frequency* or *carrier frequency*. These control schemes are often used in variable-frequency motor control inverters because they allow a wide range of output voltage and frequency adjustment while also improving the quality of the waveform.

Multilevel inverters provide another approach to harmonic cancellation. Multilevel inverters provide an output waveform that exhibits multiple steps at several voltage levels. For example, it is possible to produce a more sinusoidal wave by having split-rail [direct current](#) inputs at two voltages, or positive and negative inputs with a central [ground](#). By connecting the inverter output terminals in sequence between the positive rail and ground, the positive rail and the negative rail, the ground rail and the negative rail, then both to the ground rail, a stepped waveform is generated at the inverter output. This is an example of a three level inverter: the two voltages and ground. ^[3]

[\[edit\]](#) Three phase inverters

3-phase inverter with wye connected load

[Three-phase](#) inverters are used for [variable-frequency drive](#) applications and for high power applications such as [HVDC](#) power transmission. A basic three-phase inverter consists of three single-phase inverter switches each connected to one of the three load terminals. For the most basic control scheme, the operation of the three switches is coordinated so that one switch operates at each 60 degree point of the fundamental output waveform. This creates a line-to-line output waveform that has six steps. The six-step waveform has a zero-voltage step between the positive and negative sections of the square-wave such that the harmonics that are multiples of three are eliminated as described above. When carrier-based PWM techniques are applied to six-step waveforms, the basic overall shape, or *envelope*, of the waveform is retained so that the 3rd harmonic and its multiples are cancelled.

3-phase inverter switching circuit showing 6-step switching sequence and waveform of voltage between terminals A and C

To construct inverters with higher power ratings, two six-step three-phase inverters can be connected in parallel for a higher current rating or in series for a higher voltage rating. In either case, the output waveforms are phase shifted to obtain a 12-step waveform. If additional inverters are combined, an 18-step inverter is obtained with three inverters etc. Although inverters are usually combined for the purpose of achieving increased voltage or current ratings, the quality of the waveform is improved as well.

[\[edit\]](#) History

[\[edit\]](#) Early inverters

From 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 sets). 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 [thyatron](#).

The origins of electromechanical inverters explain the source of the term *inverter*. Early AC-to-DC converters used an induction or synchronous AC motor direct-connected to a generator (dynamo) so that the generator's 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 and only one field frame. The result with either is AC-in, DC-out. With an M-G 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.^{[4][5]}

[\[edit\]](#) Controlled rectifier inverters

Since early transistors were not available with sufficient voltage and current ratings for most inverter applications, it was the 1957 introduction of the [thyristor](#) or [silicon-controlled rectifier](#) (SCR) that initiated the transition to [solid state](#) inverter circuits.

12-pulse line-commutated inverter circuit

The *commutation* requirements of SCRs are a key consideration in SCR circuit designs. SCRs do not turn off or *commutate* automatically when the gate control signal is shut off. They only turn off when the forward current is reduced to zero through some external

process. For SCRs connected to an AC power source, commutation occurs naturally every time the polarity of the source voltage reverses. SCRs connected to a DC power source usually require a means of forced commutation that forces the current to zero when commutation is required. The least complicated SCR circuits employ natural commutation rather than forced commutation. With the addition of forced commutation circuits, SCRs have been used in the types of inverter circuits described above.

In applications where inverters transfer power from a DC power source to an AC power source, it is possible to use AC-to-DC controlled rectifier circuits operating in the inversion mode. In the inversion mode, a controlled rectifier circuit operates as a line commutated inverter. This type of operation can be used in HVDC power transmission systems and in [regenerative braking](#) operation of motor control systems.

Another type of SCR inverter circuit is the current source input (CSI) inverter. A CSI inverter is the [dual](#) of a six-step voltage source inverter. With a current source inverter, the DC power supply is configured as a [current source](#) rather than a [voltage source](#). The inverter SCRs are switched in a six-step sequence to direct the current to a three-phase AC load as a stepped current waveform. CSI inverter commutation methods include load commutation and parallel capacitor commutation. With both methods, the input current regulation assists the commutation. With load commutation, the load is a synchronous motor operated at a leading power factor.

As they have become available in higher voltage and current ratings, semiconductors such as transistors that can be turned off by means of control signals have become the preferred switching components for use in inverter circuits.

[\[edit\]](#) Rectifier and inverter pulse numbers

Rectifier circuits are often classified by the number of current pulses that flow to the DC side of the rectifier per cycle of AC input voltage. A [single-phase half-wave rectifier](#) is a one-pulse circuit and a [single-phase full-wave rectifier](#) is a two-pulse circuit. A three-phase half-wave rectifier is a three-pulse circuit and a three-phase full-wave rectifier is a six-pulse circuit.^[6]

With three-phase rectifiers, two or more rectifiers are sometimes connected in series or parallel to obtain higher voltage or current ratings. The rectifier inputs are supplied from special transformers that provide phase shifted outputs. This has the effect of phase multiplication. Six phases are obtained from two transformers, twelve phases from three transformers and so on. The associated rectifier circuits are 12-pulse rectifiers, 18-pulse rectifiers and so on.

When controlled rectifier circuits are operated in the inversion mode, they would be classified by pulse number also. Rectifier circuits that have a higher pulse number have reduced harmonic content in the AC input current and reduced ripple in the DC output voltage. In the inversion mode, circuits that have a higher pulse number have lower harmonic content in the AC output voltage waveform.

[edit] See also

- [Solar inverter](#)
- [Grid tie inverter](#)
- [Push-pull converter](#)
- [Variable-frequency drive](#)
- [Static inverter plant](#)
- [Switched-mode power supply \(SMPS\)](#)
- [Pacific Intertie HVDC power transmission line](#)

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[edit] External links

- [Solar Panel Inverters](#) explained in great detail.
- [Sine Wave Versus Modified Sine Wave Power Inverter Video](#)
- [A simple circuit with RC oscillator](#)

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