SAFETY WHEN OPERATING INVERTERS

Excerpt from Inverter Charger Series Manual

BY:

VIJAY SHARMA
ENGINEER

1.0 ELECTRICAL SHOCK - CAUSE AND EFFECT ON HUMAN BODY

1.0 General

When there is an electrical voltage difference between two points (V) and these two points are connected with an electrical conductor, electrical current (I) flows from the point at a higher voltage to the point at a lower voltage. The value of current flow is directly proportional to the voltage difference and inversely proportional to the electrical resistance (R) i.e. I = V / R. This relationship is called Ohm's Law.

The Earth is considered to have zero voltage. Any source of electrical voltage like utility / generator / battery will drive a current to the Earth if this source gets connected to the Earth through a conductor.

The human body is an electrical conductor and has an electrical resistance of around 100 Kilo Ohm when dry and 1 Kilo Ohm when wet. When a person is standing on Earth, his/her feet are at the Earth potential i.e. 0 V. If they touch a voltage source, a current will flow through their body and they will receive electrical shock.

1.2 Primary Factors

Three primary factors affect the severity of the shock a person receives when he or she is a part of an electrical circuit:

- Amount of current flowing through the body (measured in Amperes).
- Path of the current through the body.
- Length of time the body is in the circuit.

1.3 Other Factors

Other factors that may affect the severity of the shock are:

- The voltage of the current.
- The presence of moisture in the environment.
- The phase of the heart cycle when the shock occurs.
- The general health of the person prior to the shock.

1.4 Effects of Electrical Shock

Effects can range from a barely perceptible tingle to severe burns and immediate cardiac arrest. Although it is not known the exact injuries that result from any given amperage, the following TABLE 1.1 demonstrates the general relationship for a 60-cycle, hand-to-foot shock of one second's duration:

TABLE 1.1 EFFECTS OF ELECTRICAL SHOCK

CURRENT LEVEL Milliamperes, mA	PROBABLE EFFECT ON THE HUMAN BODY
1 mA	Perception level. Slight tingling sensation. Still dangerous under certain conditions.
5mA	Slight shock felt; not painful but disturbing. Average individual can let go. However, strong involuntary reactions to shocks in this range may lead to injuries.
6mA - 16mA	Painful shock, begin to lose muscular control. Commonly referred to as the freezing current or "let-go" range.
17mA - 99mA	Extreme pain, respiratory arrest, severe muscular contractions. Individual cannot let go. Death is possible.
100mA - 2000mA	Ventricular fibrillation (uneven, uncoordinated pumping of the heart). Muscular contraction and nerve damage begins to occur. Death is likely.
> 2,000mA	Cardiac arrest, internal organ damage, and severe burns. Death is probable.

For example If a person touches a live wire say at 120 VAC, the following current will flow through the body and probable severity of shock may be seen from the Table on Page 3:

- Dry body, 120V / 100K Ohm = 1 mA - mildly dangerous
- Wet body, 120V / 1K Ohm = 120 mA - very dangerous

2.0 SAFETY INSTRUCTIONS - GENERAL

2.1 Installation and wiring compliance

Installation and wiring must comply with the Local and National Electrical Codes and must be done by a CERTIFIED ELECTRICIAN.

2.2 Preventing electrical shock

- Always connect the grounding connection on the unit to the appropriate grounding system.
- Disassembly / repair should be carried out by qualified personnel only.
- Disconnect all AC and DC side connections before working on any circuits associated with the unit. Turning the ON/OFF Key on the unit to OFF position may not entirely remove dangerous voltages.
- Be careful when touching bare terminals of capacitors. The capacitors may retain high lethal voltages even after the power has been removed. Discharge the capacitors before working on the circuits.

2.3 Installation environment

- The inverter should be installed indoor only in a well ventilated, cool, dry environment.
- Do not expose to moisture, rain, snow or liquids of any type.
- To reduce the risk of overheating and fire, do not obstruct the suction and discharge openings of the cooling fans.
- To ensure proper ventilation, do not install in a low clearance compartment.

2.4 Preventing fire and explosion hazards

- Working with the unit may produce arcs or sparks. Thus, the unit should not be used in areas where there are flammable materials or gases requiring ignition protected equipment. These areas may include spaces containing gasoline-powered machinery, fuel tanks, and battery compartments.

2.5 Precautions when working with batteries

- Batteries contain corrosive diluted sulphuric acid as electrolyte. Precautions should be taken to prevent contact with skin, eyes or clothing.
- Batteries generate hydrogen and oxygen during charging resulting in evolution of explosive gas mixture. Care should be taken to ventilate the battery area and follow the battery manufacturer's recommendations.
- Never smoke or allow a spark or flame near the batteries.
- Use caution to reduce the risk of dropping a metal tool on the battery. It could spark or short circuit the battery or other electrical parts and could cause an explosion.
- Remove metal items like rings, bracelets and watches when working with batteries. The batteries can produce a short circuit current high enough to weld a ring or the like to metal and thus, cause a severe burn.
- If you need to remove a battery, always remove the ground terminal from the battery first. Make sure that all the accessories are OFF so that you do not cause a spark.

3.0 SAFETY INSTRUCTIONS - INVERTER RELATED

3.1 Preventing Paralleling of the AC Output

The AC output of the unit should never be connected directly to an Electrical Breaker Panel / Load Center which is also fed from the utility power / generator.

Such a direct connection may result in parallel operation of the different power sources and AC power from the utility / generator will be fed back into the unit which will instantly damage the output section of the unit and may also pose a fire and safety hazard.

If an Electrical Breaker Panel / Load Center is fed from this unit and this panel is also required to be fed from additional alternate AC sources, the AC power from all the AC sources like the utility / generator / this unit should first be fed to an Automatic / Manual Selector Switch and the output of the Selector Switch should be connected to the Electrical Breaker Panel / Load Center. ***CAUTION: To prevent possibility of paralleling and severe damage to the unit, never use a simple jumper cable with a male plug on both ends to connect the AC output of the unit to a handy wall receptacle in the home / RV.***

3.2 Connecting to Multi-Wire Branch Circuits

Do not directly connect the Hot / Line output of this unit simultaneously to the two Hot Legs L1 and L2 of the 120 / 240 VAC Split Phase Electrical Breaker Panel / Load Center where Multi-Wire (common Neutral) Branch Circuit Wiring method is used for distribution of AC power. This may lead to overloading / overheating of the Neutral conductor of the distribution wiring system and is a risk of fire.

A suitable external transformer with a Split Phase output (Isolated or Auto-Transformer) of suitable power rating (25% more than the Apparent Power (VA) rating of this unit) with Primary of 120 VAC and Secondary of 120 / 240 VAC (Two 120 VAC Split Phases 180 degrees apart) should be used. The Hot and Neutral of the 120 VAC output of this unit should be fed to the Primary of this external transformer and the 2 Hot outputs (120V AC Split Phases) and the Neutral from the Secondary of this external transformer should be connected to the two Hot Legs L1 and L2 of the 120 / 240 VAC Electrical Breaker Panel / Load Center.

3.3 Preventing Input Over-Voltage

It is to be ensured that the DC input voltage of this unit does not exceed 16.8 + / - 0.3 VDC for the 12V battery version and 33.6 + / - 0.6 VDC for the 24V battery version to prevent permanent damage to the unit. Please observe the following precautions:

- Ensure that the maximum charging voltage of the external battery charger / alternator / solar charge controller does not exceed 16.8 + / - 0.3 VDC for the 12V battery version and 33.6 + / - 0.6 VDC for the 24V battery version.
- Do not use unregulated solar panels to charge the battery connected to this unit. Under cold ambient temperatures, the output of the solar panel may reach >22 VDC for 12V Battery System and > 44 VDC for the 24V Battery system. Always use a charge controller between the solar panel and the battery.
- Do not connect this unit to a battery system with a voltage higher than the rated battery input voltage of the unit (e.g. do not connect the 12V version of the unit to 24V battery system or the 24V version to the 48V Battery System)

3.4 Preventing Reverse Polarity on the Input Side

When making battery connections on the input side, make sure that the polarity of battery connections is correct (Connect the Positive of the battery to the Positive terminal of the unit and the Negative of the battery to the Negative terminal of the unit). If the input is connected in reverse polarity, DC fuse(s) inside the inverter will blow and may also cause permanent damage to the inverter.

3.5 Using Generator as External Input Source with Inverter Chargers

The AC output voltage of a generator is proportional to its rotational speed (RPM – Revolutions Per Minute) and the current fed to its field windings. The frequency of the AC output voltage produced by the generator is proportional to the RPM of the engine and the number of poles used in the generator. The RPM of the generator is controlled and kept constant by the mechanical governor installed on the engine that is driving the generator. The output voltage of the generator is controlled by its electrical voltage regulator, which controls the current fed to its field windings.

When an electrical load is applied to the generator, its output voltage tends to drop and the speed of the engine also tends to drop leading to drop in the output frequency and additional drop in the output voltage. The drop in the RPM of the engine is countered by the engine governor by feeding more fuel to the engine. The drop in voltage of the generator is countered by the voltage regulator of the generator by increasing the current fed to the field windings.

Similarly, when a load is removed from the generator, its output voltage tends to rise and the RPM of the engine also tends to rise leading to increase in the output frequency and additional increase in the output voltage. The increase in the RPM of the engine is countered by the engine governor by reducing the fuel supply to the engine. The rise in the output voltage of the generator is countered by the voltage regulator of the generator by decreasing the current fed to the field windings.

The mechanical governor and electrical voltage regulator have sensitivity of producing controlling action to correct a deviation of the controlled parameter. Higher sensitivity tends to produce oscillations around the controlled value. Hence, when these devices try to control very fast moving parameters, they will produce larger oscillations before settling down. The voltage regulator will tend to produce high voltage transients during this time. **These symptoms are seen during the start up and shut down of the engine-generator.**

For 60 Hz frequency of AC voltage, the engine speeds should be 3600 RPM for 2 pole, 1800 RPM for 4 pole and 1200 RPM for 6 pole generators.

When a generator is started, it is cold and it starts from 0 RPM and reaches the rated RPM within a finite time. Thus, during the initial period of ramping up from 0 RPM to the rated RPM, its frequency and output voltage will be fluctuating due to the regulating action of the mechanical governor and the electrical voltage regulator. As this happens in a very short duration during this period, the output frequency will fluctuate and the output voltage will also fluctuate and will contain a lot of high voltage transients that are produced by the extremely fast regulating actions of the mechanical governor and the voltage regulator. These voltage and frequency fluctuations and high voltage transients can damage the AC loads that are fed from the generator. Also, the engine needs some time to warm up and stabilize in its mechanical operation. **Normally, the engine-generator should be warmed up for at least 10 minutes before loading the generator.**

The same fluctuations in frequency and voltage and appearance of high voltage transients will be seen at the output of the generator at the time of shutting down the engine. ***CAUTION: It is very important that all AC loads on the output of the generator are switched on only after around 10 minutes of generator starting. This ensures that the engine and generator have warmed up sufficiently and that the generator is providing stable frequency and a well regulated, cleaner, transient-free output voltage to prevent damage to the AC loads / Inverter Charger. Similarly, the AC loads should be disconnected first, before the engine is shut down.***

For more information, visit: **www.samlexamerica.com**