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120 / 240 VAC SINGLE SPLIT PHASE & MULTI-WIRE BRANCH CIRCUITS

Excerpt from Inverter Charger Series Manual

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INFO

For purposes of explaining the concept of Multi-wire Branch Circuits, Neutral to Ground bonding and Equipment Grounding Conductor (EGC) have not been shown in the schematic diagrams.

1.0 120/240 VAC SINGLE SPLIT PHASE SYSTEM

Inverters and Inverter Chargers are frequently connected to a building / structure / house that has been previously completely wired for 120 / 240 VAC Single Split Phase System and has a standard Service Entrance Panel / Load Center / Distribution Panel – See Fig. 1.

120/240 VAC Single Split Phase Utility Power to the building / structure / house is fed from a Distribution Transformer that is either mounted on a utility pole (feeds through overhead lines) or on the ground on a concrete pad (Pad mounted, feeding through underground lines). This power enters the building / structure / house through the Service Entrance Panel for further internal distribution.

1.1 Service Entrance Panel For 120 / 240 VAC Split Phase AC Power Distribution

Fig. 1 below illustrates the residential 120 / 240 VAC, Single Split Phase, 3- Pole, 4 Wire Grounding System, which was inherited from Edison's early DC distribution networks.

120 / 240 VAC Split Phase Electrical power from the utility (called Service)is fed through an electrical power meter to a load center / breaker panel for further distribution. This panel is called the Service Entrance Panel. This panel normally has the following components:

- Main Incoming Circuit Breaker – e.g. 200 A capacity
- Circuit Breakers feeding various branch circuits – e.g. 15 A , 20 A, 30 A, 50 A capacities
- Bus bar for Grounded Conductor (GC) / Neutral
- Bus bar for Equipment Grounding Conductors (EGC)
- Bus bar for connection to Grounding Electrode (GE)

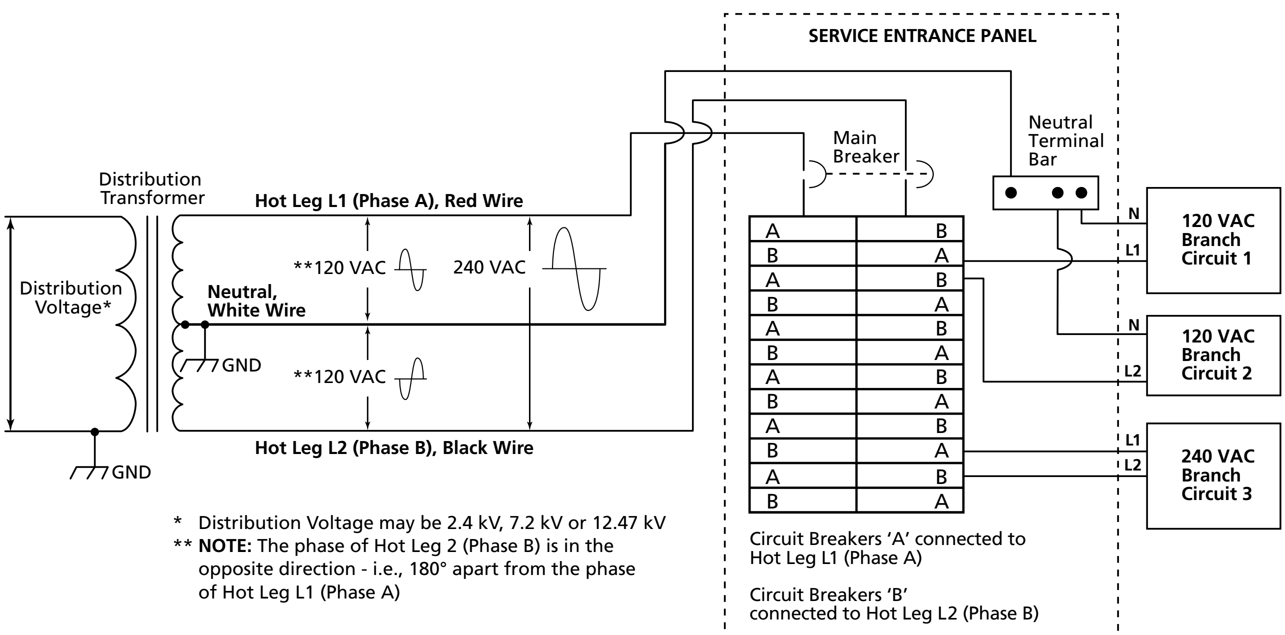

Fig. 1: 120 / 240 VAC Single Split Phase, 3-Wire Distribution System

The primary side of the Distribution Transformer is connected between Ground and one of the 2400V, 7.2 kV, 12.47 kV, 13.2 kV or 13.8 kV phases of the utility company's 3-Phase Distribution Network. The secondary of the Distribution Transformer has a grounded center tap and is wound in a manner that supplies two 120 VAC phases which are 180° out of phase with each other (Split Phases). In urban areas, one Distribution Transformer typically supplies 1-6 residences.

The center-tapped configuration of the secondary side of the Distribution Transformer provides following voltages to the Service Entrance Panel:

- 120 VAC between the Hot Leg L1 (Phase A, Red wire) and the grounded, center tapped Neutral (White wire). The oscilloscope trace of the voltage waveform between the Hot Leg L1 and Neutral shows the voltage rising in the Positive direction at the start of the waveform
- 120 VAC between the Hot Leg L2 (Phase B, Black wire) and the grounded, center tapped Neutral (White wire). Please note that the corresponding oscilloscope trace of the voltage waveform between the Hot Leg L2 and Neutral shows the voltage rising in the Negative direction at the start of the waveform. **This indicates that the two 120 VAC voltages are 180 degrees out of phase.**
- 240 VAC between the Hot Leg L1 (Phase A, Red wire) and the Hot Leg L2 (Phase B, Black wire)

A part of a typical Service Entrance Panel with interleaved type of bus bar arrangement with 2-columns of branch circuit breakers (marked “A” and “B”) is shown in Fig. 8.1. Each Full Sized Breaker (marked “A” or “B”) originates on the opposite phase from the one above or below it. Breakers marked “A” are connected to the Hot Leg L1 (Phase A) and breakers marked “B” are connected to the Hot Leg L2 (Phase B). Going down a column of Full Size Breakers, they will be in a phase sequence of A-B-A-B…

- 120 VAC branch circuit loads are connected between a breaker on Phase A (Hot Leg L1, Red wire) and Neutral (N, White wire) as shown for Branch Circuit 1 or between a breaker on Phase B (Hot Leg L2, Black wire) and Neutral (N, White wire) as shown for Branch Circuit 2
- 240 V branch circuit loads are connected between a breaker on Phase A (Hot Leg L1, Red wire) and Phase B (Hot Leg L2, Black wire) as shown for Branch Circuit 3.

2.0 MULTI-WIRE BRANCH CIRCUITS

As explained above, in a utility-connected, 120 / 240 VAC Single Split Phase System, the 120 / 240 VAC power consists of two 120 VAC lines viz. Hot L1 (Phase A, Red wire) and Hot L2 (Phase B, Black wire) that are 180 degrees out of phase with respect to the center tapped, grounded Neutral (White wire) – see Fig. 1

It is possible to wire two separate 120 VAC Branch Circuits fed from the 2 split phases Hot L1 (Phase A, Red wire) and Hot L2 (Phase B, Black wire) using a single common Neutral (White wire) instead of two separate Neutrals (White wires) – See the two 15 A Branch Circuits feeding the 2 receptacles shown in Figs. 8.4.This type of connection is called a Multi-wire Branch Circuit. As the phases of the two 15 A, 120 VAC Branch Circuits feeding the 2 receptacles are 180 degrees apart and oppose each other, the net current flowing in the common Neutral (White wire) will be equal to the difference of the currents in the two Branch Circuits (15 A – 15 A = 0 A). The maximum current flowing in the common Neutral will be limited to the breaker capacity (Maximum current will flow in the common Neutral when one of the split phase branch circuits is not loaded and the loaded split phase branch circuit is drawing its full rated capacity). Proper safety guidelines for Multi-wire Branch Circuits are to be adhered to as laid down in Section 100 of the National Electrical Code (NEC).

WARNING!

Never remove the Neutral (White wire) from the Neutral Terminal Bar in the Service Entrance Panel / Load Center / Distribution Panel if the phase conductors are energized — it could be part of a Multi-wire Branch Circuit, and removing it could damage the connected electrical loads / cause a fire.

Removal of the Neutral wire will amount to the two 120 VAC loads being connected in series across 240 VAC. If the impedances of the two 120 VAC loads are not equal (have different Watt ratings), the load with the higher impedance (higher watt rating) will see a dangerous over voltage condition > 120 VAC and may reach 240 VAC in case the other load is shorted (please see example in Fig 2 on page 3).

2.1 Examples Of Multi-Wire Branch Circuits

The most common Multi-wire Branch Circuit is for the dishwasher and disposal circuits. Other common uses are for lighting circuits, for the two small appliance branch circuits required at the kitchen counters and for “home runs” back to a panel. The idea is that the electrician can save the cost of installing another wire by using the Multi-wire Branch Circuit for 2 circuits going to approximately the same area in the house

2.2 Recognizing Multi-Wire Branch Circuits

The NEC requires that Multi-wire Branch Circuits in some, but not all, cases use a two-pole circuit breaker so that both circuits are dead at the same time under fault conditions and for servicing. This two-pole, side-by-side circuit breaker rated at 15 or 20 amps may be one indication that

Multi-wire Branch Circuits have been used. Common handle (ganged) circuit breakers rated at 30 amps and higher are usually dedicated to 240 Volt circuits for ranges, hot water heaters, dryers, and the like.

Examination of the wiring in the Service Entrance Panel / Load Center / Distribution Panel may show a three-wire cable (14 or 12 AWG red, black, and white conductors) with bare ground leaving the Service Entrance Panel / Load Center / Distribution Panel. This may be connected to a Multi-wire Branch Circuit. The circuit breakers connected to this cable and the outputs of this cable should be traced to determine the presence or absence of a Multi-wire Branch Circuit.

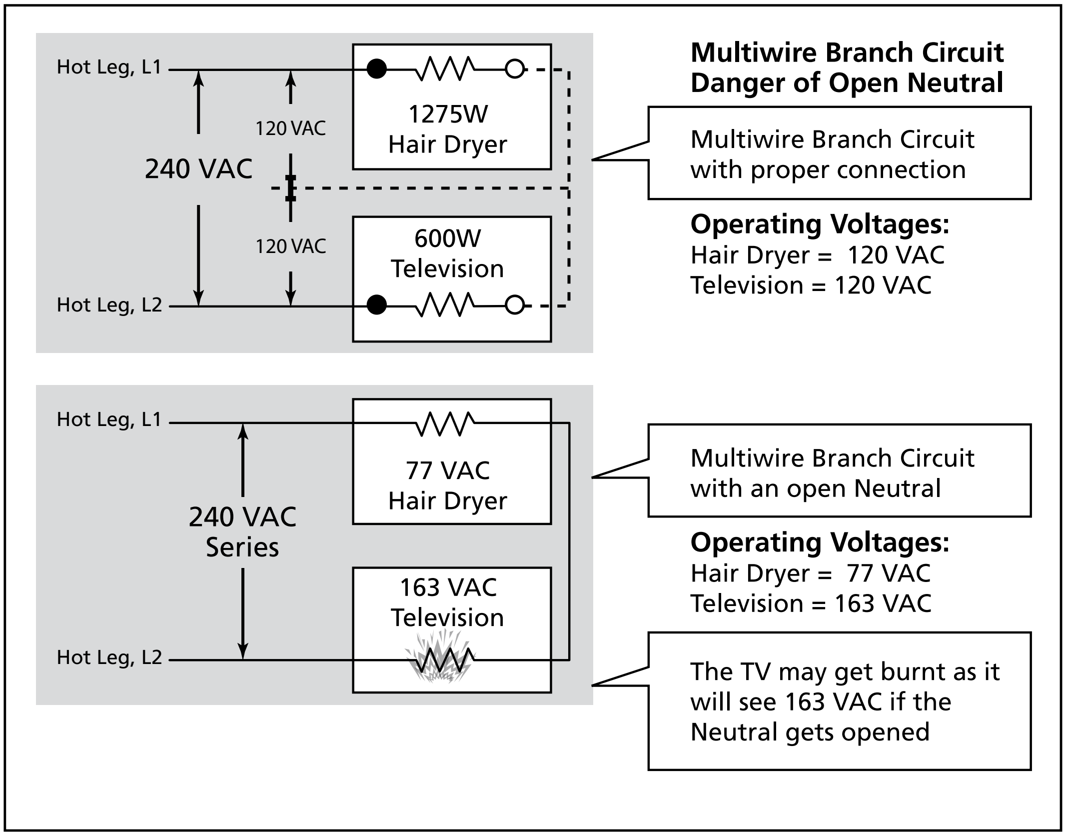

Fig. 2: Multi-wire Branch Circuit – Danger of open Neutral

3.0 OVER-LOADING OF COMMON NEUTRAL CONDUCTOR IN THE MULTI-WIRE BRANCH CIRCUITS

3.1 When An Inverter Is Connected Directly To 120 / 240 VAC Service Entrance Panel / Load Center / Distribution Panel

As explained above, a Multi-wire Branch Circuit operates normally and safely only when the two separate 120 VAC Branch Circuits are fed from the 2 split phases L1 (Phase A, Red wire) and L2 (Phase B, Black wire) that are 180 degrees apart and which results in a lower current flow in the single common Neutral (this current will be = the difference in the currents in the two individual Split Phase Branch Circuits).

Each branch circuit in the Service Entrance Panel / Load Center / Distribution Panel is protected by a circuit breaker in the hot, ungrounded current carrying conductor fed from the Hot Leg L1 / L2. This ungrounded, current carrying conductor is sized based on the Ampere rating of the circuit breaker. The Neutral, grounded current carrying conductor is usually the same size as the Hot ungrounded current carrying conductor fed from the Hot Leg L1 / L2. This Neutral conductor will be overloaded / overheated if it is forced to carry current higher than the Ampere rating of the circuit breaker resulting in fire and safety hazard.

The Neutral wiring in a Multi-wire Branch Circuit may get overloaded when a single 120 VAC inverter is directly connected to both the Hot Legs L1 and L2 on the 120 / 240 VAC Service Entrance Panel / Load Center / Distribution Panel as in shown in Fig. 3. Please note that both the L1 and L2 Hot input terminals of the Main Breaker in the Service Entrance Panel / Load Center / Distribution Panel have been bonded (shorted) to energize both the Hot L1 and L2 legs together in parallel with the Hot output wire of the inverter. In this case, the two 120 VAC Hot Legs L1 and L2 are being delivered voltage from a single 120 VAC inverter and this voltage is in phase on both the Hot Legs L1 and L2 of the panel. Fig 3 shows two 15 A Branch Circuits feeding two 15 A receptacles that have been wired as Multi-wire Branch Circuits. Each Branch Circuit is delivering 15 A and the voltages / currents in the two branches are in phase. Hence, the return current in the common Neutral from the two Branch Circuits will add to 30 A and not subtract to 0 A. Thus, the 15 A rated Neutral conductor will be forced to carry 30 A which is double its rated Ampere capacity and hence, will get overheated resulting in a safety and fire hazard (see Fig 3).

4.0 OPTIONS FOR OVERCOMING OVER-LOADING OF COMMON NEUTRAL CONDUCTOR IN THE MULTI-WIRE BRANCH CIRCUITS

When An Inverter Is Connected Directly To 120 / 240 V Service Entrance Panel / Load Center / Distribution Panel

The following options are suggested for dealing with this problem:

- Disconnect or rewire the Multi-wire Branch Circuits as separate circuits (also called “home run”) from the Service Entrance Panel / Load Center / Distribution Panel.
- Connect both "Hot" (ungrounded) conductors of the Multi-wire Branch Circuit to a single circuit breaker rated for the ampacity of the Neutral conductor.
- Limit the output of the inverter with a circuit breaker rated at the ampacity of the Neutral conductor (usually 15 amps). Place a warning near this circuit breaker stating that the rating must not be increased.
- A suitable transformer with a Split Phase output (Isolated or Auto-Transformer) of suitable power rating (25 % more than the Surge Power (VA) rating of the inverter) 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 trans¬former and the 2 Hot outputs (120 VAC Split Phases) and the Neutral from the Secondary of this transformer should be connected to the two Hot Legs L1 and L2 of the 120 / 240 VAC Service Entrance Panel / Load Center / Distribution Panel (see Fig. 4 page 5).

Section 690-10 of the NEC provides requirements and allowances on connecting a single inverter to a code-compliant AC wiring system.

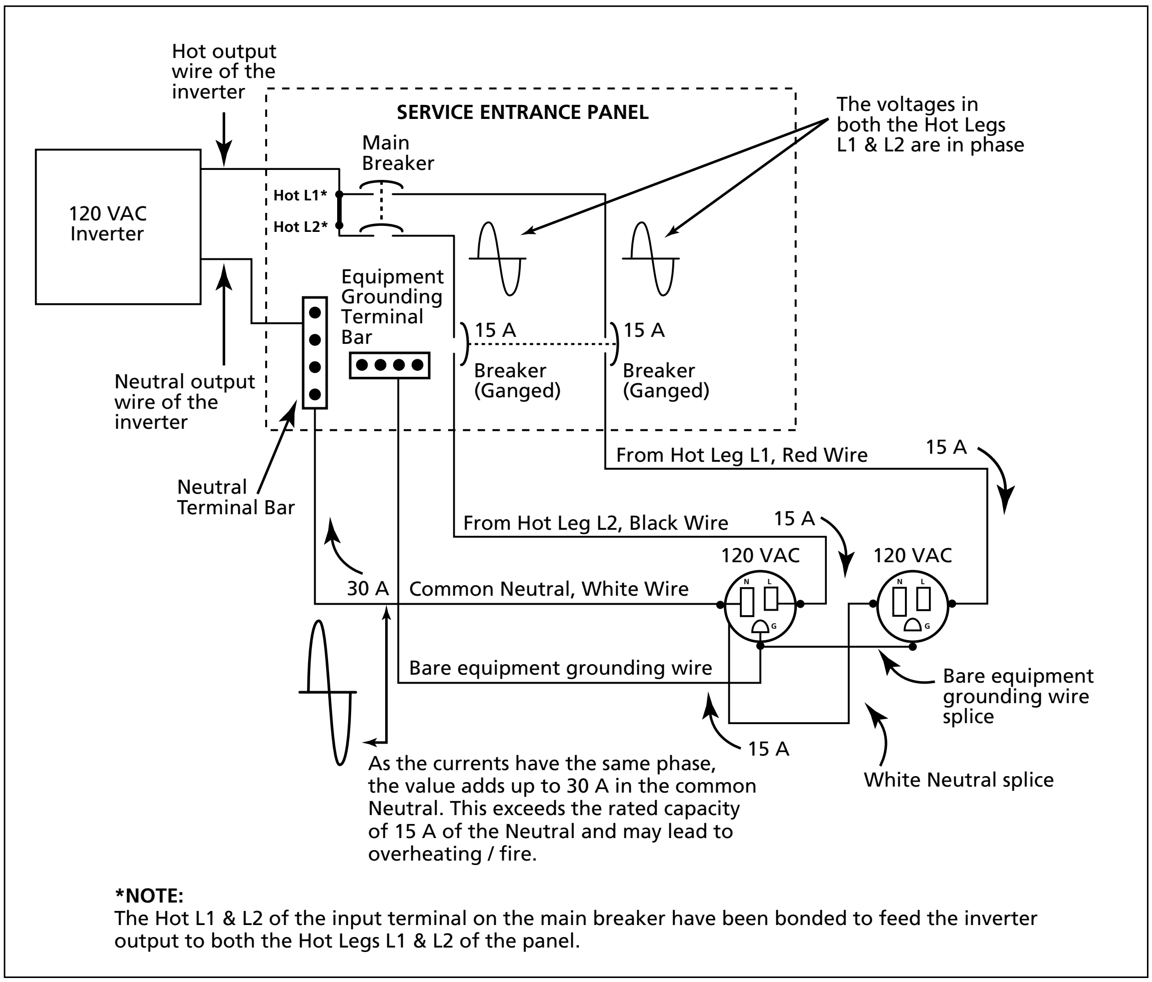

Fig 3: 120 VAC, Single Phase Inverter Directly Feeding a Multi-Wire Branch Circuit in a 120 / 240 Service Entrance Panel / Load Center / Distribution Panel

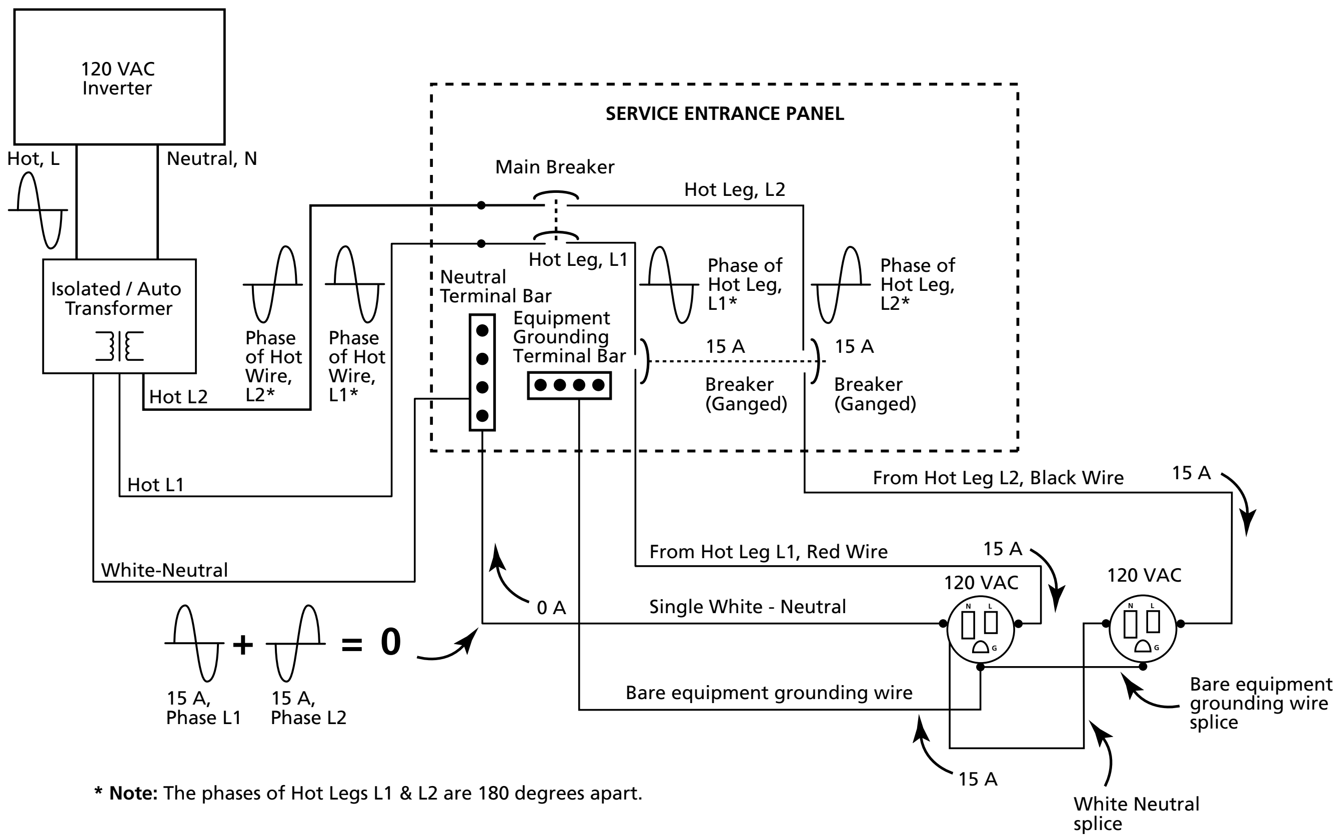

Fig. 4: Connecting inverter to the Service Entrance Panel / Load Center / Distribution Panel through a transformer to accommodate Multi-wire Branch Circuits

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