SAE INTERNATIONAL

SURFACE VEHICLE RECOMMENDED PRACTICE

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Auxiliary Power Unit Electrical Interface Requirements for Class Eight Trucks

RATIONALE

Replace "Must" with "Shall" makes the document clearer.

1. SCOPE

This SAE Recommended Practice covers the design and application of a 120 VAC single phase engine based auxiliary power unit or GENSET. This document is intended to provide design direction for the single phase nominal 120 VAC as it interfaces within the truck architecture providing power to truck sleeper cab hotel loads so that they may operate with the main propulsion engine turned off.

1.1 Purpose

The purpose of this Recommended Practice is to provide design direction for the single phase nominal 120 VAC APU as it interfaces within the truck architecture providing power to truck sleeper cab user loads, HVAC loads, and vehicle battery charging, so that they may operate with the main propulsion engine turned off.

- This Recommended Practice applies to factory and after-market installed APU systems providing 120 VAC single phase power as a convenience for operator and passenger use. APUs are intended to power user loads not essential to vehicle operation or safety (e.g., HVAC, TV, microwave ovens, battery chargers for mobile phones or laptop computers, audio equipment, etc.).
- Systems typically incorporate a diesel engine, a generator, a control system and power distribution wiring. Requirements are given for the performance, safety, reliability, and environmental compatibility of the system.
- These are recommended guidelines to be used by OEM and APU or GENSET manufacturers in the development of their own specifications, which may incorporate more or less stringent requirements.
- This Recommended Practice scope excludes military vehicles, bus and 28 V systems.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
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2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1113-1 Electromagnetic Compatibility Measurement Procedures and Limits for Components of Vehicles, Boats (up to 15 m), and Machines (Except Aircraft) (16.6 Hz to 18 GHz)

SAE J1113-11 Immunity to Conducted Transients on Power Leads

SAE J1113-12 Electrical Interference by Conduction and Coupling—Capacitive and Inductive Coupling via Lines Other than Supply Lines

SAE J1113-13 Electromagnetic Compatibility Measurement Procedure for Vehicle Components—Part 13: Immunity to Electrostatic Discharge

SAE J1113-42 Electromagnetic Compatibility—Component Test Procedure—Part 42—Conducted Transient Emissions

SAE J1127 Low Voltage Battery Cable

SAE J1128 Low Voltage Primary Cable

SAE J1455 Recommended Environmental Practices for Electronic Equipment Design in Heavy-Duty Vehicle Applications

SAE J1673 High Voltage Automotive Wiring Assembly Design

SAE J1773 SAE Electric Vehicle Inductively Coupled Charging

SAE J1939-15 Reduced Physical Layer, 250K bits/sec, Un-Shielded Twisted Pair (UTP)

SAE J2698 Primary Single Phase Nominal 120 VAC Wiring Distribution Assembly Design—Truck and Bus

2.1.2 Other EMC standards

CISPR 25 Level 3

FCC Part 15, Class B

2.1.3 Other standards

NFPA 70 (National Electrical Code)

ABYC Recommended Practice E-11 and A31

NEC 2008 – National Electrical Code 2008 edition

2.1.4 Underwriters Laboratories Publication

UL 1699 Arc-Fault Circuit Interrupters

UL 943 Ground Fault Circuit Interrupter

2.1.5 Canadian Standards Association

CSA 22.2 No. 107.1-01 General use Power Supplies

3. ABBREVIATIONS AND DEFINITIONS

3.1 NEC

National Electric Code 2008

3.2 AMPACITY

Current carry capacity of a conductor.

3.3 THD

Total Harmonic Distortion

3.4 AFCI

Arc Fault Circuit Interrupter

3.5 GFCI

Ground Fault Circuit Interrupter

3.6 Nominal 120 VAC

3.7 Standard electrical voltage supplied by electric utilities may vary from 100 to 130 VAC and is referenced in this document as nominal 120 VAC.

3.8 SHORE POWER

A fixed pedestal or other fixture that provides the interface to the truck for electricity from the land based power grid. An extension cord links the shore power with the truck's fixed shore power connectors.

3.9 SURGE CURRENT

The initial current drawn by a load on startup. This surge is typically less than 1 s.

4. GENERAL APPLICATION CONSIDERATIONS

4.1 Location of Device

The area or location where the device will be mounted is typically on the frame rail behind the cab and fuel tanks, usually on the right hand side of the truck.

4.2 Maximum Surge Requirements

The system designer needs to ensure that the selected engine/APU combination can satisfy the startup surge requirements of the expected loads. This start-up surge current of a single phase induction motor can be up to six times the steady state current and is typically less than a second in duration. Televisions and microwaves also have startup surge requirements. A high startup surge may appear to the APU as a short circuit. The designer needs to ensure that the output circuit breaker does not trip under these conditions.

4.3 Steady State Power Requirements

The system designer shall size the system based on the steady state power requirements of the expected loads. The expected loads shall include all loads which will be connected and operated simultaneously and accommodate the startup surges of cyclical loads. For a typical truck cab this would include TV, VCR/DVD player, refrigerator, and light. Consideration shall also be given to engine sizing to ensure sufficient prime mover power given engine de-rating based on temperature and altitude, and efficiencies of the generator and drivetrain. Appendix A provides a sample of the typical steady state loads of common appliances used in the trucking industry. These are not exact and the designer shall confirm ratings to be used.

4.4 Technology Choices

There are at least three types of generators that can be used for APUs. Synchronous type generators shall be driven at synchronous speed to ensure correct frequency output, usually 3600 rpm or 1800 rpm for a two pole or four pole generators, respectively. These generators require an external electronic voltage regulator to supply the required excitation and output voltage regulation. Induction type generators shall be driven at slightly over synchronous speed and utilize a run capacitor to provide excitation and voltage regulation. Synchronous generators typically have very good output sinusoidal waveforms with low Total Harmonic Distortion (THD). By contrast, induction generators typically have high THD output waveforms, up to 40% THD can be expected. Permanent magnet generators are self excited and require an inverter to produce a regulated 120 VAC output. The inverter design determines the output waveform that may be square wave, quasi sine wave, or sine wave. Each type has its characteristic THD with the sine wave having the lowest THD.

All devices designed for 120 VAC operation are designed to operate on a low THD voltage, typical of the waveform provided by the utility. Many devices are not compatible with, or will operate differently on high THD waveforms.

Examples include the following:

- microwave ovens that may cook slower or faster
- digital clocks which derive their timebase from the incoming power (i.e., non crystal-controlled clocks) may not keep time properly
- speed controlled tools or light dimmers may not work properly
- potential for video or audio interference on A/V equipment
- some GFCI breakers do not operate correctly and become unsafe

NOTE: Figure 1 depicts examples of system architecture including transfer switch wiring and power sources. APU and Shore Power are not connected in parallel. Transfer switches are recommended and typical wiring is shown in 5.1.7.

Examples of system architecture

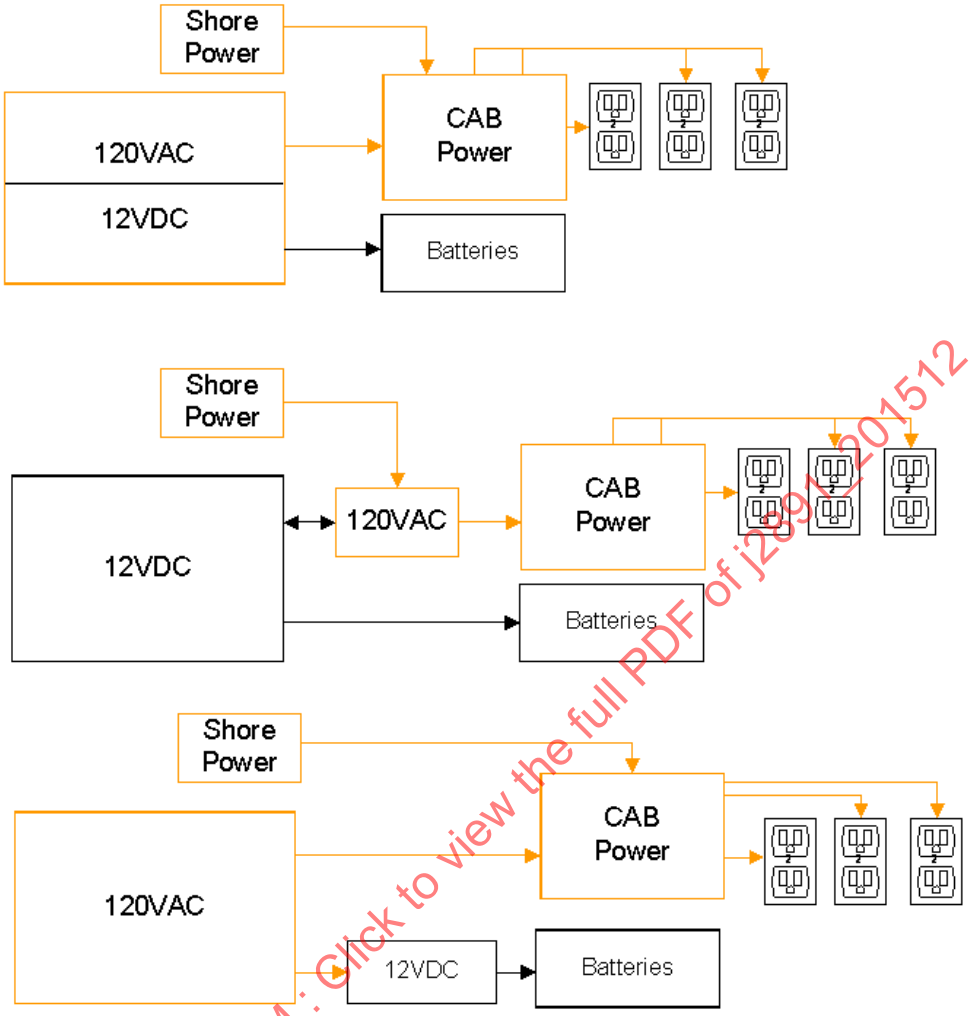

FIGURE 1 - EXAMPLES OF SYSTEM ARCHITECTURE WITH TRANSFER POWER SOURCES
(THESE ARE NOT APU AND SHORE POWER IN PARALLEL DEPICTIONS)
TRANSFER SWITCH TYPICAL WIRING IS SHOWN IN 5.1.7

4.5 Power Distribution

4.5.1 Over Current Protection

Typical system configuration requires an over-current protection device (circuit breaker) at the AC power output of the APU. This over-current device shall be mounted on or very near to the generator and shall be reasonably accessible from outside the vehicle. The over-current device shall be sized to allow expected surge currents, and the total steady-state current, but shall act quickly to break the circuit in case of a short circuit. The device may be either thermally activated or magnetically activated. If a thermally activated device is chosen, the device's ambient temperature de-rating curve shall be accounted for to ensure full load capability at extreme high ambient temperatures, and adequate circuit protection at extreme low ambient temperatures.

4.5.2 Wiring and Cabling

Wire selection, routing and installation shall follow SAE J2698. Typically the AC wiring is routed into the cab through the cab floor. Care shall be taken to ensure the entry point of the wiring is grommeted to minimize water intrusion and wire chafing. The wiring or cabling may additionally be placed within an armored conduit for increased protection. Wire color coding to follow the NEC standard, black for hot, white for neutral, and green for safety or earth ground. 120 VAC harnesses shall be covered with an orange covering material per SAE J1673 to identify them as high voltage.

4.5.3 Connectors and Terminals

Any connector utilized for APU output power shall be listed by UL and or CSA, and be rated for the required voltage, current, and temperature. The connector shall be keyed for polarity and have a positive locking mechanism. Additionally, when the connector is mated, the ground terminal shall make contact before the hot and neutral terminals.

4.5.4 GFCI/AFCI Compatibility

Where GFCI and/or AFCI protection is required for APU output circuits the designer shall be aware that some GFCI and AFCI devices may not function correctly with high THD generators. The designer shall ensure that the selected GFCI or AFCI device models are compatible with the selected APU generator by testing the selected devices on the selected generator according to the appropriate UL standards (UL943 for GFCI and UL1699 for AFCI).

5. ELECTRICAL PERFORMANCE

5.1 AC Output

5.1.1 Waveform

Sine wave, 5 to 40% THD

5.1.2 Voltage

120 VAC (±10%)

5.1.3 Frequency

60 Hz (±5%)

5.1.4 Current

At a minimum, the APU current rating shall be based on the steady state and surge currents of the expected loads.

5.1.5 Isolation Voltage to Chassis

Isolation of voltage to chassis is meant to describe the voltage that may be sustained between 120 VAC and 12 VDC and their respective ground. NEC 250.34 defines the distinctions between portable and vehicle-mounted generators. Bonding to ground is a fundamental part of voltage isolation and is defined in 5.1.7 and in NEC 250.30.

NOTE: This indicates the frame of the generator need not be connected to earth and that the frame may serve as the ground (in place of earth). It is also commonly believed that the generator would be a “separately derived system” because of the interconnection between the shore and APU. Because the Neutral is switched, there is no electrical connection between the shore and APU, thus the generator shall be bonded as per 250.30. That basically means the neutral wire shall be bonded to the generator frame. Therefore it is believed that the conclusion is to bond the neutral to generator frame and ground the generator frame to the vehicle frame. This seems consistent with the general architecture - a bonded neutral, a switched neutral ATS (Automatic Transfer Switch), and grounding the generator set frame to the vehicle chassis. In this case, also this ensures that shorting the hot to the vehicle chassis will blow the fuse in the generator. If the neutral was left floating, it would not blow the fuse. As for the ground being galvanically connected to the DC side, this is true, and shall be considered by the designer. There is a possible path between the two within any appliances that are both connected to 120 VAC and 12 VDC.

National Electrical Code
250.34 Generators—Portable and Vehicle-Mounted
(A) Portable Generators. The frame of a portable generator isn’t required to be grounded to the earth if:
  (1) The generator only supplies equipment or receptacles mounted on the generator, and
  (2) The metal parts of the generator and the receptacle grounding terminal are bonded to the generator frame.
(B) Vehicle-Mounted Generators. The frame of a vehicle-mounted generator isn’t required to be grounded to the earth if:
  (1) The generator frame is bonded to the vehicle frame,
  (2) The generator only supplies equipment or receptacles mounted on the vehicle or generator, and
  (3) The metal parts of the generator and the receptacle grounding terminal are bonded to the generator frame.
(C) Grounded Neutral Conductor Bonding. If the portable generator is a separately derived system (transfer switch opens the grounded neutral conductor), then the portable generator shall be grounded and bonded in accordance with 250.30.

5.1.6 APU with Shore Power Transfer System

This can be an external transfer switch, or internal to the APU. The transfer switch shall meet NEC/UL requirements and may also meet NEC article 626 Truck Stop Electrification (TSE) guidelines. The transfer system shall provide backfeed protection, i.e., it shall prevent the appearance of the APU output voltage on the shore power line in the case of a single fault condition (e.g., the transfer relay contacts becoming welded).

5.1.7 Neutral to Ground Bonding

The truck’s AC voltage system neutral shall be locally bonded to the truck chassis when the APU is selected as the AC power source. When the truck’s AC distribution system is powered via shore power, the neutral to ground bonding is implemented at the utility power source and shall NOT be locally bonded to the truck chassis.

Figures 2 through 4 illustrate examples of bonding for different installations. Considerations for bonding shall follow SAE J2698 recommendations.

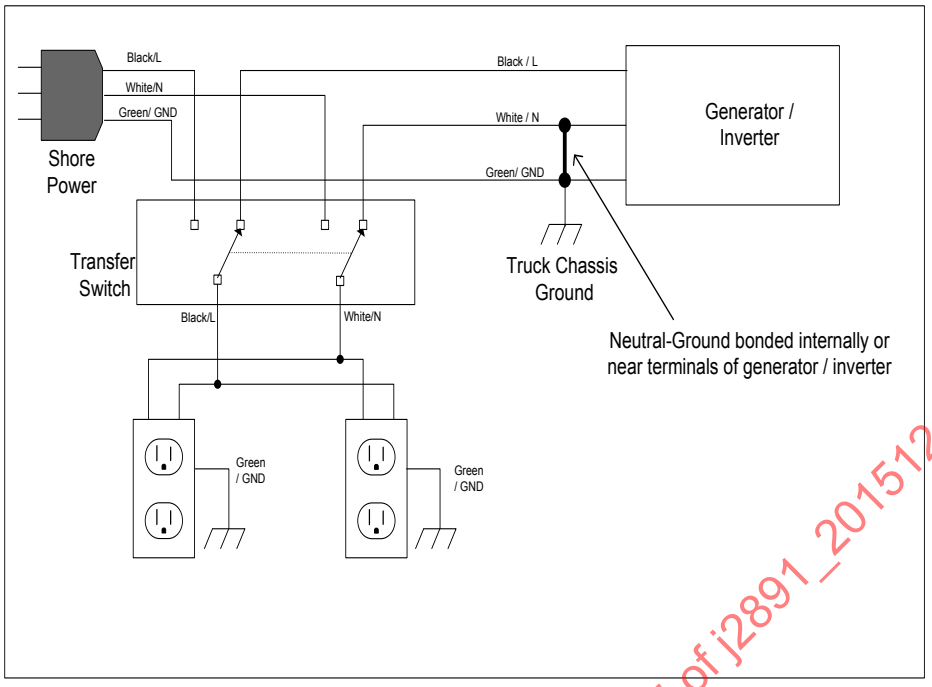

FIGURE 2 - NEUTRAL BONDING WITH EXTERNAL TRANSFER SWITCH

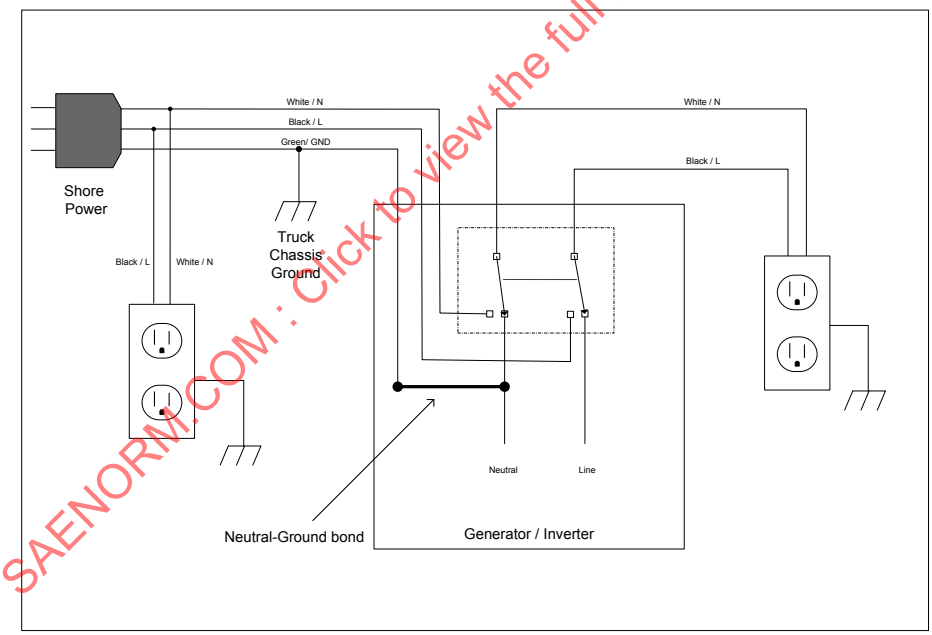

FIGURE 3 - NEUTRAL BONDING WITH INTERNAL TRANSFER SWITCH