14. APTA PR-E-RP-015-99 Recommended Practice for Head End Power Source Characteristics

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Abstract: This recommended practice defines the characteristics necessary on new equipment for head end power (HEP) sources, including diesel-driven alternators, inverters and utility-supplied wayside power. The HEP source is comprised of power source, switchgear, control system (incorporating trainline complete functions) and connections to vehicle HEP trainline(s).

Keywords: head end power source, trainline, 480 VAC

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1. Overview

1.1 Scope

This recommended practice defines the characteristics necessary on new equipment for head end power (HEP) sources, including diesel-driven alternators, inverters and utility-supplied wayside power. The HEP source is comprised of power source, switchgear, control system (incorporating trainline complete functions) and connections to vehicle HEP trainline(s). For a description of the HEP trainline system and the load characteristics, refer to *APTA PR-E-RP-016-99, Recommended Practice for 480 VAC Head End Power System*[1].

The passenger rail industry phased this recommended practice into practice over the six-month period from July 1 to December 31, 1999. The recommended practice took effect January 1, 2000.

1.2 Purpose

This document defines the recommended practices for HEP Sources to allow intermixing of cars and locomotives of varying designs. In addition, it defines minimum HEP source construction recommended practices for new equipment.

Equipment conforming to this recommended practice should be mutually compatible for HEP operation (with some limitations, as described in section 4.2)

For special functions not already in general use, it is recommended that the specifying entity, be it an authority or railroad, approach APTA for a recommendation as to how to address the property-specific functions.

When new equipment specifications are under development, it is highly advisable that the writer(s) carefully review the trainline control system requirements (both electrical and mechanical) with the specifying entity (which will for convenience herein be called an "authority"; "railroad" will be used to indicate the operating, as opposed to specifying, entity) to identify any subtle issues that may not be contained in this document.

2. References

APTA PR-E-S-001-99, Standard for Insulation Integrity

APTA PR-E-RP-002-98, Recommended Practice for Wiring of Passenger Equipment

APTA PR-E-RP-009-98, Recommended Practice for Wire Used on Passenger Rolling Stock

[1] For references in Italics, see Section 2.

APTA PR-E-RP-011-98, Recommended Practice for Head End Power Load Testing

APTA PR-E-RP-016-99, Recommended Practice for 480 VAC Head End Power System

APTA PR-E-RP-017-99, Recommended Practice for 27-Point Control and Communication Trainlines for Locomotives and Locomotive Hauled Equipment.

49 CFR 229.7(a) Prohibited Acts, October 2000

Information Technology Industry Council, Application Note and Curve, Voltage versus Duration (http://www.itic.org/iss_pol/techdocs/curve.pdf)

3. Definitions, abbreviations and acronyms

3.1 Definitions

For the purpose of this recommended practice, the following definitions apply.

3.1.1 dead bus protection: A control system feature that confirms that the HEP bus is not energized (dead bus) before allowing the local output contractor to close. This prevents inadvertently connecting two HEP sources to the same bus.

3.1.2 fixed jumper: A variation of an HEP jumper cable in which only one end is provided with a plug, while the remaining end is provided with a flange for mounting on a vehicle. This approach is taken to permanently affix the jumper to the vehicle and reduce the number of contacts, since they are only present on one end rather than two.

3.1.3 head end power (HEP): A system by which 480 VAC 3-phase electrical power, to operate auxiliaries, is provided to railroad vehicles from a central source via a trainline system. The power source can be locomotive (hence "Head End"), power car, or wayside source.

3.1.4 HEP jumper cable: A cable assembly, having the necessary power and control conductors and equipped with a plug on one or both ends, which is used to provide a flexible electrical connection between two cars and/ or locomotives or a wayside equipment.

3.1.5 HEP receptacles: The receptacles mounted on the ends of rail vehicles and wayside equipment into which the HEP jumper cables mate.

3.1.6 HEP source: A source of HEP: locomotive, power car or wayside power.

3.1.7 HEP switchgear: The contactors, circuit breakers, power switches, overload protection and associated control components used to connect the HEP power source to the trainline system.

3.1.8 HEP system, single bus: A form of HEP transmission system in which there is a single electrical bus running the length of the train. All four jumpers connecting adjacent vehicles are wired in parallel.

3.1.9 HEP system, split bus: A form of HEP transmission system in which there are two independent electrical buses running the length of the train, a train left and train right (relative to the forward direction of the train). The buses may be fed HEP independently from separate sources, such as two locomotives. Two of the jumpers connecting vehicles are wired in parallel to the left bus, and two to the right bus. Vehicle loads may be divided so as to take some power from each bus.

3.1.10 HEP trainline: An electrical cable system which allows HEP to be transmitted over the entire length of a train. It includes both power and control conductors. The trainline may provide power to equipment in each vehicle, or may simply pass straight through, providing a power path between vehicles on opposite ends of that vehicle.

3.1.11 load box: A piece of wayside equipment used to provide a test load for an HEP source to allow its performance to be measured. The equipment consists of a variable resistance load, cooling fan, load control switching, control panel and instrumentation.

3.1.12 looping: The process of connecting a jumper cable between two adjacent receptacles (or a fixed jumper and adjacent receptacle) on the same vehicle. This is normally done on the exposed end of the first and last vehicles of a train and establishes the trainline complete circuit. Locomotives having the F-end HEP receptacles disconnected through the use of an isolation switch use an internal loop circuit and do not require an F-end loop.

When wayside power is applied via the end of the consist, the far end of the train is looped in the normal fashion, the wayside feed end is looped between left and right sides of the train and the wayside power connected with one jumper on each side of the train.

3.1.13 normal mode: On a locomotive where the prime mover drives both the traction alternator and the HEP alternator, the operating mode in which HEP is supplied by the HEP alternator.

3.1.14 portable jumper: A form of an HEP jumper cable in which both ends are provided with plugs. This approach is taken to allow the jumper cable to be easily removed from the vehicle and moved elsewhere.

3.1.15 power car: For purposes of this document, a power car is a rail vehicle, other than a locomotive, containing a HEP source and control system. This generally takes the form of a baggage car or a car converted from a locomotive that has had the traction system removed.

3.1.16 short looping: The process of looping the HEP jumpers at points other than the ends of the train. This is used in an emergency situation such as a damaged jumper on the road to bypass an open trainline complete circuit on one side of the train.

CAUTION - When short looped, vehicles behind the short loop site do not have the TLC indication or control interlock at the HEP controls, even though the 480VAC circuits may be live.

3.1.17 standby mode: On a locomotive where the prime mover drives both the traction alternator and the HEP alternator, the operating mode in which HEP is supplied by the traction alternator. In this mode, the locomotive cannot supply traction power. This mode is used primarily in terminals since the engine should consume less fuel and generate less noise when operating in this mode, as it operates at a lower speed than in Normal Mode.

3.1.18 trainline complete (TLC): A series continuity check circuit, originating at the HEP control system, used to determine that all HEP trainline jumper cables throughout the entire length of the consist are plugged in correctly. The circuit provides an indication at the HEP control panel and is interlocked with the HEP main contractor/ circuit breaker to allow the trainlines to be energized only when the TLC is established.

CAUTION – The practice of shortlooping will negate the TLC protection and is generally prohibited except when absolutely necessary to protect the health and well-being of passengers.

3.1.19 wayside power: An installation which provides HEP from a ground-based source, used to provide power to the consist when the on-board source is unavailable, such as in a yard. Generally, utility power is used, though sometimes a diesel generator is provided.

4. Technical information

4.1 General

4.1.1 HEP source recommended practices

The HEP source should be comprised of:

- Power source
- Switchgear (on-off as well as overload and other protection)
- Control system (incorporating trainline complete functions)
- Connections to vehicle HEP trainline(s)
- Battery charger, powered from the HEP bus

4.1.2 Power sources

There are four source configurations for HEP:

- Alternator driven from locomotive traction prime mover
- Alternator driven from exclusive engine
- Locomotive inverter
- Wayside power (stationary utility)

4.2 HEP trainline configurations

Two alternative approaches for the HEP trainline system are available: Single and Split Bus. Split bus allows the train to be fed from two independent HEP sources simultaneously, which may allow larger consist power demand. Single bus is used on some commuter equipment and most intercity equipment. Split bus is used on some commuter equipment. The single bus system is recommended, primarily on considerations of lower first cost, less complexity, more widespread usage, and increased operational flexibility.

Individual railroad operating practices and rules govern the intermixing of single and split bus equipment. However, for purposes of this document, the alternative approaches are semi compatible as follows:

- Single Bus source can feed Single Bus, Split Bus or mixed consist
- Split Bus source can only feed a Split Bus consist
- Single Bus and Split Bus equipment can be intermixed within a consist provided the HEP source is Single Bus and both Split Buses are utilized throughout the length of the consist.

It is incumbent upon the authority to specify which of the two following configurations the power source should take:

1. Single Bus only
2. Split Bus or Single Bus (The source is configured to provide power either way, depending upon the setup switch position.)

4.2.1 Single bus HEP system attributes

- One HEP bus the length of the train
- 480 VAC, 3 Phase, 3-wire, ungrounded system, 60 Hz operation (The source may have a neutral ground reference, but the distribution system and the load do not.)
- 1600 Amp continuous rating
- 4 jumpers across each car-car-locomotive connection (see Figure 1)
- All 4 jumpers in parallel
- Power schematic per Figure 2
- Control schematic per Figure 4

4.2.2 Split bus HEP system attributes

- Two HEP buses the length of the train, one on each side
- 480 VAC, 3 Phase, 3-wire, ungrounded system, 60 Hz Operation. (The source may have a neutral ground reference, but the distribution system and the load do not.)
- 800 Amp continuous rating per bus
- 4 jumpers across each car-car-locomotive connection (see Figure 1)
- 2 jumpers in parallel for left bus, 2 jumpers in parallel for right bus
- Power schematic per Figure 3

– Control schematic per Figure 4

4.3 Rating

The entire HEP trainline system should be rated for continuous service over the outside ambient temperature of –40 to +110 degrees F, unless otherwise specified by the authority.

The equipment should be suitably rated for the mechanical conditions experienced on the vehicle, especially shock, vibration and ambient temperatures. As these conditions are site and vehicle specific, they should be specified by the authority in contract specification documents.

4.4 Phase rotation

Phase rotation should be A, B, C, with HEP power pins designated: 1=A, 2=B, 3=C.

4.5 TLC trainline complete function of a train

4.5.1 Operation

The TLC control functions as follows: (Refer to figure 5)

The control system of the active HEP source (see 4.5.2) applies control voltage to 480-volt trainline “A” control contact #1. The resulting current flows rearward along the "A" trainline to the rear of the consist, where the looped jumper connects control contact #1 of trainline “A” to control contact #1 of trainline “B”. The current now travels forward on trainline “B” all the way to the front of the train, where it is similarly looped to trainline “A”. Finally, the current again flows rearward back to the active HEP control system where it energizes the left-side TLC relay. This relay provides an indication to the operator of consist TLC status and establishes one of the prerequisites for closing the HEP power contractor. (Refer to 5.5 for further details.)

An identical circuit on the right hand side of the consist is established via HEP trainlines “C” and “D”, with a corresponding right-side TLC relay.

Should a locomotive be turned end-for-end in the train, as in an MU arrangement, the basic TLC function is maintained, though current routing rearward/ forward may be altered.

4.5.2 Active sources

Since several HEP sources (locomotives and or power cars) could be present in a consist at the same time, switching is mandatory so that only the “active” HEP source (the one actually supplying HEP) is connected to the TLC trainlines. The TLC circuits revert to “pass through” on inactive HEP source vehicles. Refer to figure 4. This is essential to prevent false TLC indication, which could otherwise result from the interaction of the HEP control systems of two separate HEP sources.

4.5.3 Indicator lights

The separate left and right hand indicator lights are important to the operator, for if TLC is not established, it identifies which side of the consist has the problem, reducing the sites to inspect by one half.

4.5.4 Short looping

Passenger train short looping is a practice used by some railroads to avoid train delays due to certain HEP conduction problems. Short looping is accomplished by a short jumper cable that electronically connects the two adjacent HEP connectors located on one side of a passenger car or locomotive. The consequences of short looping are:

a) It removes TLC detection from all inter-car jumper cables located downstream from the short loop that are on the same side of the train as the short loop;

b) It requires inter-car jumper cables down stream from the short loop, but on the opposite side of the train as the short loop, to carry double the current;

c) It requires the under car HEP distribution cables of the first car after the short loop to carry double the current.

Short loping causes the inter-car jumper connections downstream from and on the same side of the train as the short loop to be hot and not to be protected by the TLC circuit. This means that there is a potential danger of arcing damage and injury in the event of disconnection of a jumper cable at one of these downstream locations with the HEP still on-line.

For safety reasons, the TLC relay should not be bypassed except under the considerations listed below. FRA views the 74 volt control circuit, which includes the TLC relay, as a safety circuit on trains equipped with HEP. If the TLC relay is bypassed, it would be considered a noncomplying condition under *49 CFR 229.7(a) Prohibited Acts*[2], and a violation would be submitted. FRA would accept bypassing the TLC relay enroute, based only upon the necessity to restore the 480 volt circuit for train heating, lighting and/or air conditioning to protect the well being of passengers until the train reached the next point where repairs could be made.

After extensive discussions with the FRA, the following policy has been evolved to minimize short looping and to mitigate the potential danger caused to short looping:

a) No work will be done on electrical cables between cars or any portion of the HEP system unless the HEP system is shutdown and secured;

b) When making up passenger trains in yards, short looping passenger trains is totally prohibited;

c) If the train loses head end power after leaving the yard, attempts will be made to restore the power without resorting to short looping;

d) If the train must be short looped to avoid a significant delay, the engineer and conductor will be notified in writing;

e) If a train is short looped, the repair points enroute will be notified and the problem will be repaired at the train's destination.

[2] For references in Italics, see Section 2.

4.6 TLC trainline function from wayside

The basic operation of TLC when HEP is fed from a wayside source is similar to that of a train as described in 4.5 above, with a few differences: Refer to figure 6.

a) Only one TLC circuit is provided for both sides of the consist, rather than two.

b) The HEP feed end of the consist is also looped, between left and right sides of the consist. This results in the TLC current path through control trainlines “A” to “B” to “C” to “D” and then to the TLC relay.

c) No “through” trainline feed switching is provided in the wayside source, since the wayside is always the only active HEP source for the consist.

5. Vehicle-based HEP sources

5.1 Diesel-electric locomotive, alternator driven from traction prime mover

In this arrangement, a single prime mover mechanically drives both a traction and an HEP alternator, providing power for both functions.

5.1.1 Engine

The engine should be capable of operating in three modes, as determined by the 'HEP Mode" switch (see 5.5.1 and 5.6.4)

- HEP Off: Traditional diesel throttle response for traction.
- Normal HEP: Engine operates at a constant speed, regardless of throttle position, and HEP alternator provides HEP to train; traction alternator provides power for traction.
- Standby HEP: Engine operates at constant, though reduced speed; traction alternator provides power to HEP loads; no traction power is available.

5.1.2 HEP alternator and regulator

The HEP alternator should be rated for continuous operation, as well as overload operation with a service factor, consistent with the authority's specified requirements. The rating should be stated at 480 VAC, 3-phase, 60 Hz with a 0.8 power factor. The machine should be way-connected, with a high impedance ground (consistent with the ground fault detection requirements of 8.1.2 and 8.2.2) to the locomotive car body.

The alternator should be connected to a suitable voltage regulator, which incorporates a constant voltage-to-frequency ratio feature, over the normal HEP operating speed range of the engine.

5.1.3 Traction alternator

The traction alternator should be rated for continuous operation consistent with the authority's specified requirements. Should the rating be lower than that of the HEP alternator, either electrically or for prime mover restrictions, this should be clearly stated in the builder's documentation; likewise, appropriate overload protection should be provided in the control system.

The alternator should be connected to a suitable voltage regulator, which provides a constant voltage-to-frequency ratio over the normal HEP operating speed range of the engine.

5.1.4 Locomotive control system

The locomotive control system should be configured so that when operating in the normal HEP mode, the requirements for HEP are met first, and the power remaining from the prime mover is available for traction. The majority of the traction engine control, protection and annunciation functionality resides with the locomotive control system.

5.2 Locomotive or power car, alternator driven from exclusive engine

In this arrangement, a dedicated diesel engine (or other type of engine) drives the HEP alternator. This arrangement can also be used in a stationary application to provide wayside power. When used on a locomotive, the entire HEP plant should be completely self sufficient for continuous operation, not requiring operation of the main engine for any reason whatsoever. This includes, but is not limited to, engine cooling system as well as HEP electrical equipment cooling, control power, etc.

5.2.1 Engine

The engine selected should be well suited for reliable operation in the railroad environment, consistent section with 4.3.

It is recommended that the engine be equipped with a layover heat system, which keeps the engine warm and allows easy starting and brief warm up times. This system should be powered from the HEP bus, downstream of the line contractor, so it can be fed from an external source, either wayside power or another vehicle.

5.2.2 Alternator and regulator

The HEP alternator should be rated for continuous operation, as well as overload operation with a service factor, consistent with the authority's specified requirements. Rating should be stated at 480 VAC, 3-phase, 60 Hz with a 0.8 power factor. The machine should be a wye-connected machine, with a high impedance ground to the locomotive car body.

The alternator should be connected to a suitable voltage regulator, which incorporates a constant voltage-to-frequency ratio feature, over the normal operating speed range of the engine.

5.2.3 Engine control system and indicators

The engine control and protection system should protect the engine from damage, at a minimum including the following indications. Integrated displays, LED’s or lamps may be used; if lamps, they shall be equipped with a lamp-test feature:

- Low lube oil pressure — Red
- Low coolant level — Red

– Low lube oil level	Red
– Hot engine	Red
– Overspeed	Red
– Crankcase over pressure (diesel engine only)	Red

An engine start station and control panel should be provided, located near the HEP engine. The enclosure, as well as controls mounted on its exterior, should be specified to be moisture and oil resistant in accordance with applicable NEMA or other standards. Cooling air should be provided when the HEP system is operating to allow the equipment to operate without overheating over the entire vehicle exterior ambient operating range, without regard to the traction engine status. Controls provided at the start station should include the following at a minimum:

- Starter fuse with knife switch or circuit breaker (if electric starter)
- Air cutout cock (if air starter)
- Start push button
- Stop push button
- Emergency stop pushbutton
- Emergency stop function from MU trainline command (associated with the #3 wire, as described in *APTA PR-E-RP-017-99*)
- Stop push button, remote mounted in the locomotive cab (locomotive only)

Under normal “Stop” operation, a cool down period should be provided; however, under “Emergency stop” no cool down is allowed.

An HEP engine failure should result in an alarm sounding in the locomotive cab, via energizing the #2 MU trainline circuit, "alarm bell", as described in *APTA PR-E-RP-017-99*.

Monitor panels, at the engine or other appropriate location(s), should include the following gauges at a minimum:

- Oil pressure
- Engine temperature
- Dirty air filter warning
- Fuel pressure

5.3 Diesel-electric locomotive - inverter HEP

In this arrangement, a single prime mover drives the main alternator, which usually provides energy for both traction and an HEP inverter via a DC bus.

5.3.1 Engine

The engine should be capable of operating in two modes, as determined by the "HEP mode ' switch (see 5.5.1 and 5.6.4):

– HEP Off: Traditional diesel throttle response for traction.

– HEP On: Engine operates at a throttle-dependent speed, however traction idle results in an engine speed higher than normal idle to accommodate large but normal-sized HEP step loads (minimum of 120 kW) without bogging.

5.3.2 Inverter

A solid state inverter should be provided, rated for continuous operation as well as overload operation with a service factor, consistent with the authority's specified requirements. Rating should be stated at 480 VAC, 3-phase, 60 Hz with a 0.8 power factor. The unit should be connected through a high impedance ground to the locomotive carbody.

The inverter should be equipped with diagnostic circuitry that provides indication of operating status and defects.

5.3.3 Locomotive control system

The locomotive control system should be configured so that when operating in the HEP mode, the requirements for HEP are met first, and the power remaining from the prime mover is available for traction. The majority of the traction engine control, protection and annunciation functionality should reside with the locomotive control system.

5.4 Electric locomotive - inverter HEP

The main transformer (or third rail) with some form of converter supplies energy to a DC bus. The HEP inverter is fed from this bus. The bus may also provide energy for traction, and if so, regenerative braking should be considered as an energy source for HEP operation.

5.4.1 Inverter

A solid state inverter should be provided, rated for continuous operation as well as overload operation with a service factor, consistent with the authority's specified requirements. Rating should be stated at 480 VAC, 3-phase, 60 Hz with a 0.8 power factor. The unit should be connected through a high impedance ground to the locomotive carbody.

The inverter should be equipped with diagnostic circuitry that provides indication of operating status and defects.

5.4.2 Locomotive control

The majority of the DC bus control, protection and annunciation functionality should reside with the locomotive control system.

5.5 HEP controls

5.5.1 Control panel

The HEP installation should include one or more control panels to provide the following functions, at a minimum:

5.5.1.1 Controls

1. Start HEP push button*
    a) Commands engine governor to increase engine speed from idle to HEP speed
    b) Initiates inverter operation (when inverter used)
    c) Initiates sequence to close line contractor(s)
2. Stop HEP push button
    a) Opens line contractor(s)
    b) Commands governor to allow engine to return to idle speed
    c) Shuts off inverter operation (when inverter used)
3. Fault Reset (electrical) push button
    a) Resets electrical faults-overload, etc. It may be combined with Stop HEP button.
4. HEP Source Selector-locomotive with alternator driver by prime mover:
    a) Off position
        – HEP off on this loco
        – Trainline complete power feed is off
    b) Normal & Standby positions:
        – Configures locomotive to supply HEP in the respective mode; (see 5.1.1 and 5.6.4)
        – Energizes trainline complete feed and logic
5. HEP Source Selector- all other applications:
    a) Off position

- HEP off on this vehicle
- Trainline complete power feed is off

b) Local position

- HEP supplied by this vehicle
- Energizes trainline complete feed and logic

6. HEP Trainline Mode Selector-for vehicles equipped with F-end isolation switch:

a) Lead position (long hood trail)

- F-end receptacles isolated (see 5.6.5)
- Internal loop circuit established for F-end

Trail (short hood trail) and Pass Through positions

- F-end receptacles connected to trainline
- Internal loop circuit open; F-end now part of TLC circuit

7. HEP Trainline Mode Selector-for vehicles with split bus only:

a) Left Trainline

- Trainline complete set up for left trainline bus only
- HEP supplied to left trainline bus only

b) Right Trainline

- Trainline complete set up for right trainline bus only
- HEP supplied to right trainline bus only

Both Trainlines

- Trainline complete set up for both left and right trainlines
- HEP supplied to both left and right HEP trainline buses

*the term “push button” is used in a functional sense; in practice it may be a physical pushbutton or a touch function on an integrated display unit.

5.5.1.2 Indicators

Indicators, or equivalent, equipped with a lamp-test feature, should include, at a minimum:

– Trainline complete: left	green
– Trainline complete: right	green

– HEP	contractor closed (on this vehicle)*	green
– HEP	trainline live*	amber
– HEP	fault: over/under voltage	red
– HEP	fault: over/under frequency	red
– HEP	thermal overload trip*	red
– HEP	instantaneous overload trip*	red
– HEP	ground fault	amber

*For units with split bus HEP trainline, one indicator should be provided for each trainline

An HEP system failure should result in an alarm sounding in the locomotive cab, via energizing the #2 MU trainline circuit, "alarm bell", as described in APTA RP-E-017-99.

5.5.1.3 Meters

The following meters and/or screen readouts should be provided to show performance of the HEP system:

- Voltmeter--switchable to each of the 3 phases, reading phase-phase voltage; 2% or better accuracy at 480 VAC
- Ammeter--switchable to each of the 3 phases, reading phase current; 2% or better accuracy (For a split bus system, two ammeters and switches are required)
- Frequency meter--reading the frequency of the HEP source; +/- 0.25 Hz or better accuracy over the range of 55 to 65 Hz.

The meters or screen should be rugged industrial quality, suitable for the operating environment, including but not limited to ambient temperature range as described in 4.3.

5.5.2 Protection

Controls for the HEP should include the following protective functions (refer to section 8 for settings):

- Over current: instantaneous and thermal
- Over/ under voltage
- Over/under frequency
- Dead bus
- Ground fault (indication only, no power shutdown)
- Trainline complete (per paragraph 5.5.3)

5.5.3 Trainline complete (TLC)

A trainline complete function should be incorporated into the HEP control system to ensure that the consist trainline complete is established and maintained in order for the HEP to be on.

There should be a separate TLC trainline for each the left and right side trainlines, each provided with its own indicator light to show when continuity has been established.

On single bus systems, safety considerations dictate that both the left and right TLC be complete in order for the line contractor to close.

On split bus systems, the left TLC should control the train left power HEP trainline, while the right TLC should control the train right power HEP bus. For 'both" mode, safety considerations dictate that both left and right TLC be established before the line contractors can be closed.

The HEP Source Selector (see 5.5.1) should operate so that when the HEP system is not in operation, the electrical feed to the Trainline Complete circuit should be off. The TLC feed should be protected by a circuit breaker.

5.6 Switchgear

5.6.1 Safety

Safety considerations dictate that HEP electrical equipment be suitably enclosed to protect against accidental contact by personnel. Access doors are required by regulation of both OSHA and FRA (49CFR238.303) to have the warning label, "Danger 480 volts".

5.6.2 Connections to HEP trainline(s)

Connections between the HEP source and the HEP trainline should be consistent with paragraph 4.2 with regard to single or split bus configuration. The connection should take the form of a line contractor(s) to isolate the source from the HEP trainline. The switching device should not take the form of a molded case circuit breaker, as the cycle life is limited. The contractor may also serve as the circuit breaker (providing the interrupting rating is adequate), or a separate device may be provided.

Trainline connections should be as follows:

<u>Single Bus-Configuration: See Figure 8</u>

The HEP source should be connected to the trainline through a line contractor.

<u>Split Bus-Configuration: See Figure 9</u>

The HEP source should be connected to the trainlines through separate contractors for the left and right trainlines. The HEP Trainline Mode selector should provide the following options (see 5.5.1):

- Left trainline
- Right trainline

– Both trainlines

Overload protection should be provided for each contractor separately. The nominal rating of the HEP system should be available from either the left or right trainline, up to the rating of the trainline.

5.6.3 Line contractor(s)

The line contractor should be an electro-mechanical device. It should include thermal and instantaneous overload features to protect the HEP source, or these should be included in a separate circuit breaker.

5.6.4 Circuit breaker

If a separate circuit breaker is required beyond the line contractor, it should include suitable overload functions to protect the HEP source.

5.6.5 HEP source selector switch

Locomotives equipped with Normal/Standby mode should be equipped with a 480-volt switch to determine the source of the HEP, whether HEP alternator or traction alternator. The switch position should be determined by the HEP source selector switch. (See Figure 7)

5.6.6 F-end isolation switch

Locomotives having only a single operating cab and single bus HEP system should be equipped with a HEP F-end isolation switch. When installation of the switch is specified by the authority, it should include the following functions:

– Isolation of the F-end receptacles from the locomotive HEP bus

– Provide a "looping" trainline complete circuit when the switch is in the isolate position (Thus, the locomotive should not require the jumper cables to be looped on the F-end)

The switch rating should be 1600 amps. This switch should not require control power to maintain it in the closed or open position. (It is permissible for the switch to require control power for it to change position.)

The position of the switch should be controlled by HEP Trainline Mode Selector switch on the HEP control panel (see 5.5.1). Refer to Figures 4 and 8 for schematics.

5.7 Trainline connections

5.7.1 Phase rotation

Phase rotation should be A, B, C with HEP power pins designated: 1=A, 2=B, 3=C.

5.7.2 Physical connections

The trainline should be configured to provide continuity between the ends of the vehicle for both power and control (TLC) circuits without regard to whether HEP is being provided by that unit.

The pass-through capacity of the HEP trainline should meet the recommended practices of APTA-PR-E-RP-016-99 Recommended Practices for 480 VAC Head End Power System.

5.7.3 Battery charger

A battery charger, powered from the HEP bus downstream of the line contractor, should be provided. The charger should provide a redundant method of charging the HEP system battery (which might be the locomotive main battery), such that should the battery be fully discharged, it can be easily recharged by applying external power to the HEP receptacles.

6. Wayside power

6.1 General

Wayside Power can take one of two forms:

– Utility-supplied energy

– Engine-driven supplied energy

In either case, the power should be provided to the rail vehicles from wayside receptacles arranged with a pair of receptacles at each wayside outlet box location. This can be a single site, or multiple outlets, one per track. Each outlet box should be provided with its own control station and switch gear so as to allow each box to be completely independent of the others, including fault protection.

6.2 Power sources

6.2.1 Utility source

The power source should take the form of a utility-fed step down transformer; rated for continuous operation consistent with the authority's specified requirements (see Figure 10). Recommended capacity is 400 or 800 Amps per outlet box. Rating should be stated at 480 VAC, 3-phase, 60 Hz with a 0.8 power factor. The transformer should have a grounded, wye-connected secondary. In locations where the railroad employs electric traction on the tracks supplied with HEP, the grounding scheme should be coordinated with that of the traction system so as to prevent circulating currents occurring from a different potential between rails and HEP source grounds. Suitable transformer primary protection should be provided.

The design of the control system should be such that loss of control power should result in the HEP being shut off to the outlet boxes.

6.2.2 Engine-driven source

The power source should be as described in 5.2.

6.3 Control panels

6.3.1 Utility-based wayside power

6.3.1.1 Controls

Each wayside outlet box should be provided with a trackside control panel, which includes the following controls (see Figure 11):

- Key switch (to allow only authorized personnel the ability to energize the system)
- Start HEP
- Stop HEP
- Lockout control (to disable the control station)

6.3.1.2 Indicators

Each trackside control panel should include the following indicator lights, equipped with a lamp-test feature:

– Contractor open	green
– Contractor closed	red
– Trainline complete loop open	blue
– Circuit breaker open	yellow
– Circuit breaker open from ground fault	white
– Circuit breaker closed	red

6.3.1.3 Meters

The central control panel should be provided with the following meters to show performance of the overall HEP system:

- Voltmeter--switchable to each of the 3 phases, reading phase-phase voltage; 0.2% or better accuracy at 480 VAC
- Ammeter--switchable to each of the 3 phases, reading phase current; 2% or better accuracy.

The meters should be rugged industrial quality, suitable for the specified operating environment, including but not limited to the temperature range (which may be in excess of outside ambient temperature).

6.3.2 Engine-driven source wayside power

The trackside control panel should have the controls and indicators as described in 6.3.1.

The meters described above should be provided in a location near the engine. In addition the following industrial quality instrument should be provided:

> Frequency meter: reading the frequency of the HEP source; ± 0.25 Hz over the range of 55-65 Hz.

6.3.3 Protection: utility source HEP

Controls for the HEP should include the following protective functions (refer to section 8.5 for settings):

- Over current: instantaneous and thermal
- Under voltage
- Ground fault
- Dead bus (recommended only in situations where there is likelihood of backfeed from the vehicle source)

6.3.4 Protection: engine-driven source HEP

Controls for the HEP should include the following protective functions (refer to section 8.2 for settings):

- Over current: instantaneous and thermal
- Over/under voltage
- Over/under frequency
- Ground fault
- Dead bus (recommended only in situations where there is likelihood of backfeed from the vehicle source)

6.3.5 Trainline complete

A trainline complete function should be incorporated into each trackside wayside control system to ensure that the consist trainline complete is established and maintained in order for the HEP to be on. The key switch should operate so that when the HEP system is not in operation, the electrical feed to the Trainline Complete circuit should be off. The TLC feed should be fused or protected by a circuit breaker.

6.4 Switchgear

The connections between the HEP source and outlet box(s) should include a line contactor and separate circuit breaker for each outlet box.

6.4.1 Line contactor

This should be a suitably sized NEMA rated contactor.

6.4.2 Circuit breaker

A separate circuit breaker should be provided for each outlet box to provide overload and ground fault protection.

6.5 Trainline connections (see Figure 10)

6.5.1 Phase rotation

Phase rotation should be A, B, C with HEP power pins designated: 1=A, 2=B, 3=C.

6.5.2 Wayside outlet box

The wayside outlet box should consist of a waterproof enclosure in accordance with the authority's specification, equipped with a pair of 480 VAC receptacles and housings, per *APTA-PR -E-RP-016-99 Recommended Practice for 480 VAC HEP Power System.*[3]

Warning labels should be provided at the receptacles, which should be painted red.

6.5.3 Physical connections

Suitable cabling should be provided to connect the power source, switch gear and wayside outlet box to allow continuous operation at rated capacity. Wire size should ensure that voltage drop between the source and receptacles does not exceed 0.5%.

6.5.4 Battery charger

A battery charger, powered from the HEP bus downstream of the line contractor, should be provided, except on utility applications. The charger should provide a redundant method of charging the engine-starting battery, such that should the battery be fully discharged it can be easily recharged by applying external power to the HEP receptacles.

7. Tests

7.1 Wiring

Continuity, insulation resistance and dielectric tests should be conducted in accordance with *APTA Standard PR-E-S-001-98*, Insulation Integrity, on all wiring of each HEP system to ascertain that:

– No wires are unintentionally grounded

– No wires are shorted or cross connected to unintended circuits

– Continuity exists between all intended contacts of all receptacles

[3] For references in Italics, see Section 2.

– Continuity exists between trainlines and each vehicle connection to the trainline circuits

7.2 Vehicle proof-of-design test

An engineering Proof-of-Design test should be conducted on the vehicles. At a minimum, a pair of vehicles should be tested, but should there be more than one vehicle type, all types should be included in the test. This is in addition to compatibility testing with all types of existing vehicles with which the new equipment is to be operated.

This engineering test should operate each conductor of each trainline to demonstrate proper functionality.

7.3 Vehicle control system

Each HEP system should undergo a complete set of functional tests on the entire system, demonstrating:

– Operation of each control, both engine and electrical

– Operation of each indicator

– Operation of each meter

– Operation of all trainline complete features, including proper operation of all TLC modes

– Overcurrent protection: instantaneous and thermal

– Operation of over-voltage, under-voltage, over-frequency, and under-frequency protection

– Correct phase rotation

7.4 Vehicle load test

The HEP system should undergo a load box test, in accordance with *APTA PR-E-RP-011-98, Recommended Practice for Head End Power Load Testing*[4].

7.5 Wayside power commissioning tests

The wayside HEP system should undergo a complete set of commissioning tests on the entire system, demonstrating the functions on each wayside outlet box:

– Operation of each control

– Operation of each indicator

– Operation of each meter

[4] For references in Italics, see Section 2.

- Operation of all trainline complete features, including that opening TLC should result in HEP shut down
- Operation of overcurrent protection: instantaneous and thermal
- Calibration of the ground fault trip setting
- Operation of under voltage trip
- Operation of over-voltage, under-voltage, over-frequency, and under-frequency protection (for engine-driven source wayside only)
- Demonstration of HEP shutdown upon loss of control power
- Demonstration that the HEP system can deliver full rated power to each wayside outlet and full system rated capacity
- Demonstration that the voltage at the receptacles is specification-compliant at full rated load of the system
- Demonstration of correct phase rotation at each wayside receptacle
- For engine-driven source wayside, operation of each engine control indicator and gauge.

8. HEP source characteristics:

NOTE - Guidance on suitable steady-state and transient response characteristics available from sources such as IEEE tends to be based on the performance of utility power supply systems. The values given herein are based on the best information available at the time this document was published. The public-domain ITI (CBEMA) curve listed in the references and included here as Appendix A, while written for information technology equipment, is consistent with IEEE sources, and measured performance of locomotive HEP sources indicates it is applicable as guidance in railroad applications.

8.1 Diesel electric locomotive with traction engine driven alternator HEP source

8.1.1 Steady state

Parameter	Voltage (max)	Frequency (max)
Regulation:	2%	1 Hz
Stability @ constant load:	+/-1%	+/-1 Hz
Dip, full load applied in 2-equal steps:	30%	_______
Recovery, full load applied in 2 equal steps:	To –20% in 0.5 sec., to regulation in 3 seconds	To regulation in 5 seconds

8.1.2 Shutdown/alarm

Parameter	Low Limit	High Limit	Units
Voltage:	440	510	Volts (AC rms)
Frequency:	56	64	Hz
Ground fault indication:	(N/A)	1.0	Ampere (AC rms)
Total harmonic distortion:	(N/A)	5% from 10-100% load	

8.2 HEP source characteristics: locomotive, power car or wayside with HEP alternator driven by dedicated engine source

8.2.1 Steady state

Parameter	Voltage (max)	Frequency (max)
Regulation:	2%	1 Hz.
Stability @ constant load:	+/-1%	+/-1 Hz
Dip, full load applied in 2-equal steps:	-30%	_______
Recovery, full load applied in 2 equal steps:	To -20% in 0.5 sec., to regulation in 3 seconds	To regulation in 5 seconds

8.2.2 Shutdown/alarm

Parameter	Low Limit	High Limit	Units
Voltage:	440	510	Volts (AC rms)
Frequency:	56	64	Hz
Ground fault indication:	(N/A)	1.0	Ampere (AC rms)
Total harmonic distortion:	(N/A)	5% from 10-100% load	

8.3 HEP Source Characteristics: Diesel-Electric Locomotive with Inverter HEP Source

8.3.1 Steady state

Parameter	Voltage (max)	Frequency (max)
Regulation:	2%	1 Hz
Stability @ constant load:	+/-l%	+/-1 Hz
Dip, full load applied in 2-equal steps:	-30%	(N/A)
Recovery, full load applied in 2 equal steps:	To -20% in 0.5 sec., to regulation in 3 seconds.	

8.3.2 Shutdown/alarm

Parameter	Low Limit	High Limit	Units
Voltage:	440	510	Volts (AC rms)
Frequency:	56	64	Hz
Ground fault indication:	(N/A)	1.0	Ampere (AC rms)
Total harmonic distortion:	(N/A)	5% from 10-100% load	

8.4 HEP source characteristics: electric locomotive with inverter HEP source

8.4.1 Steady state

Parameter	Voltage (max)	Frequency (max)
Regulation:	2%	1 Hz
Stability @ constant load:	+/-1%	+/-1 Hz
Dip, full load applied in 2-equal steps:	-30%	(N/A)
Recovery, full load appliedin 2 equal steps:	To -20% in 0.5 sec., to regulation in 3 seconds.	

8.4.2 Shutdown/alarm

Parameter	Low Limit	High Limit	Units
Voltage:	440	510	Volts (AC rms)
Frequency:	56	64	Hz
Ground fault indication:	(N/A)	1.0	Ampere (AC rms)
Total harmonic distortion:	(N/A)	5% from 10-100% load	

8.5 HEP source characteristics: wayside with utility source

8.5.1 Shut down/alarm:

Parameter	Low Limit	High Limit	Units
Voltage:	440	510	Volts (AC rms)
Ground fault indication:	(N/A)	1.0	Ampere (AC rms)

9. Illustrations:

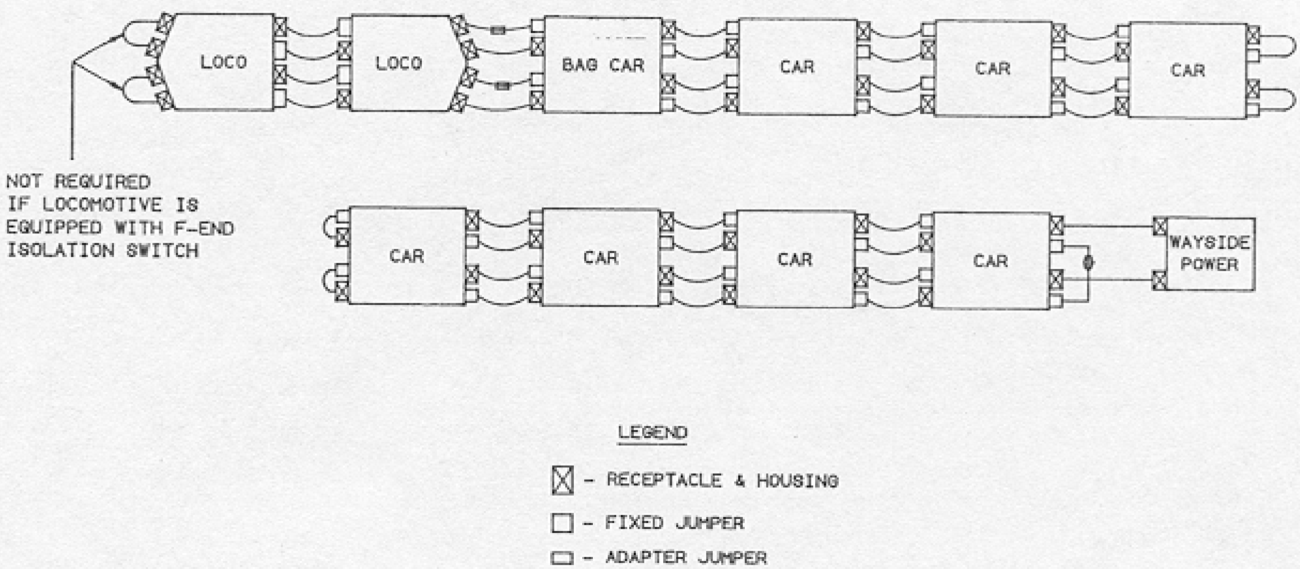


FIGURE 1
TYPICAL CONSIST HEP JUMPER CABLE ARRANGEMENT

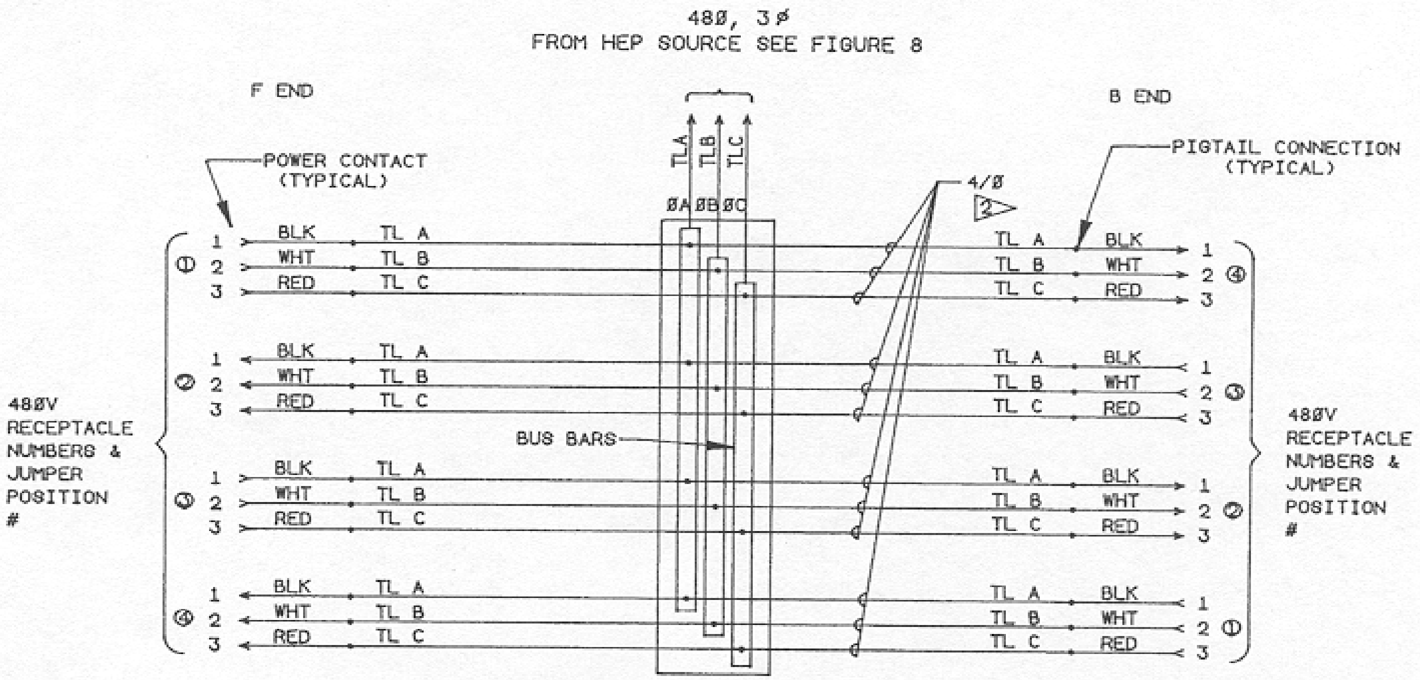


FIGURE: 2
LOCOMOTIVE
480ØV TRAINLINE
POWER SCHEMATIC
SINGLE BUS SYSTEM

NOTES

1) PHASE ROTATION: A,B,C

2) EQUIVALENT CABLE ROUTING & CAPACITY MAY BE USED

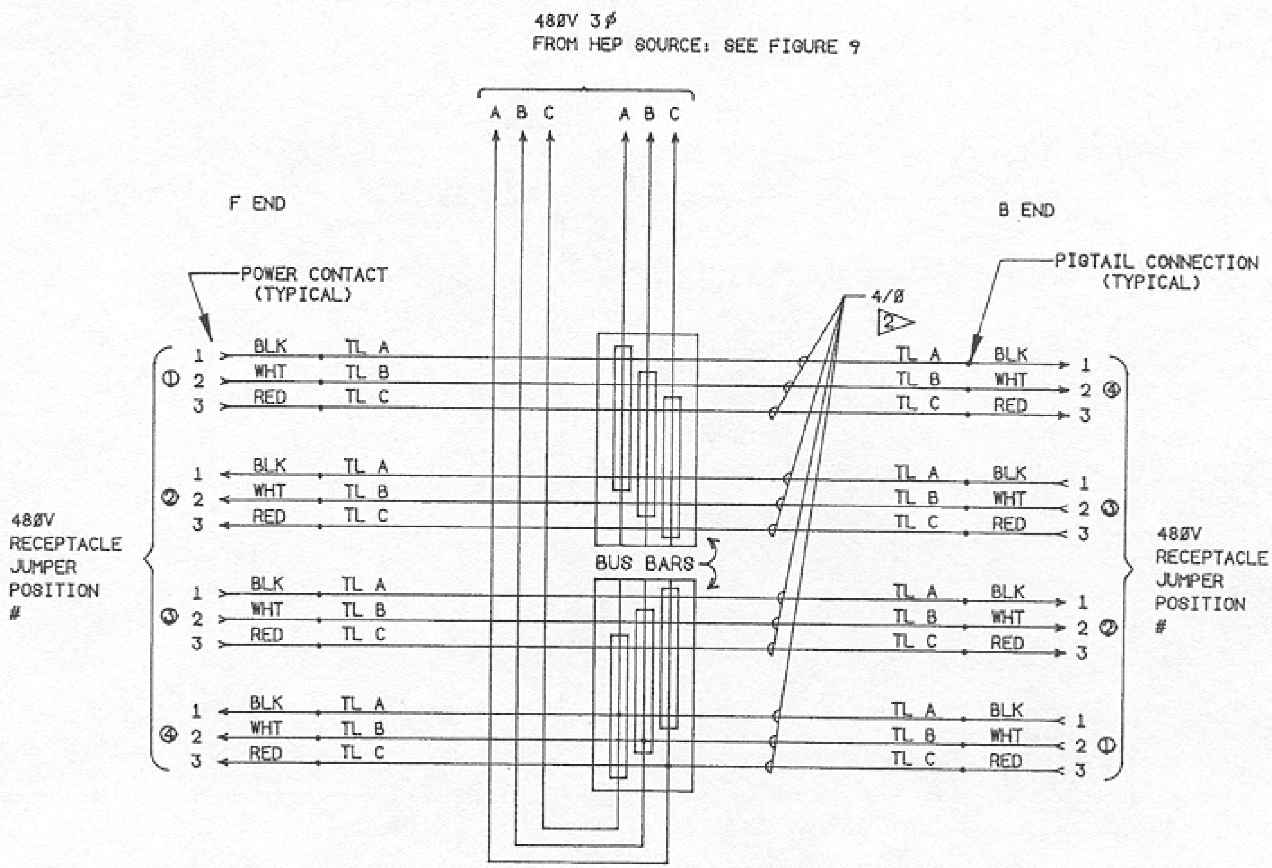


FIGURE 3
LOCOMOTIVE
480V TRAINLINE
POWER SCHEMATIC
SPLIT BUS SYSTEM

NOTES

1) PHASE ROTATION: A,B,C

2 EQUIVALENT CABLE ROUTING & CAPACITY MAY BE USED

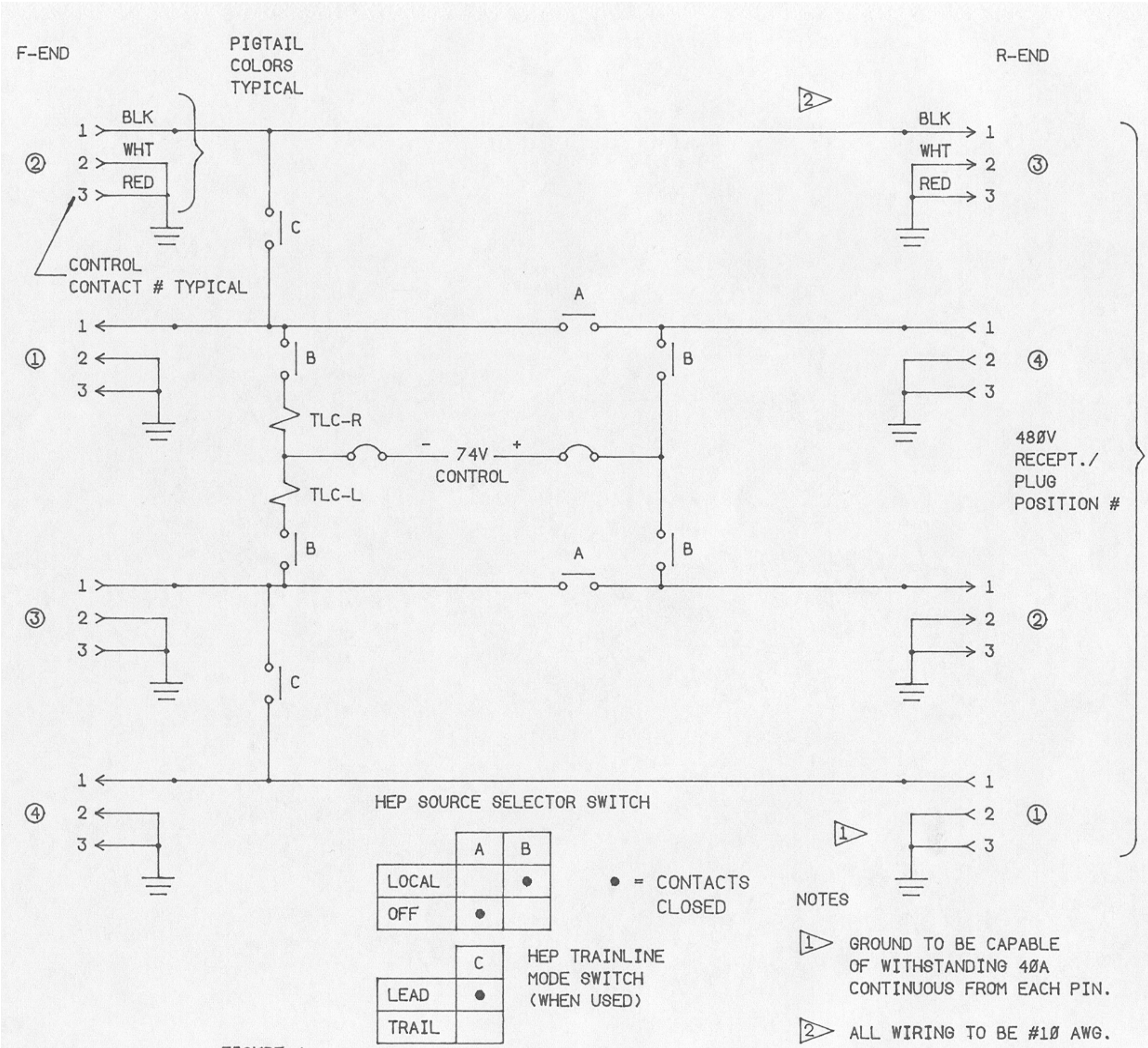


FIGURE 4
SIMPLIFIED LOCOMOTIVE 480V TRAINLINE CONTROL SCHEMATIC

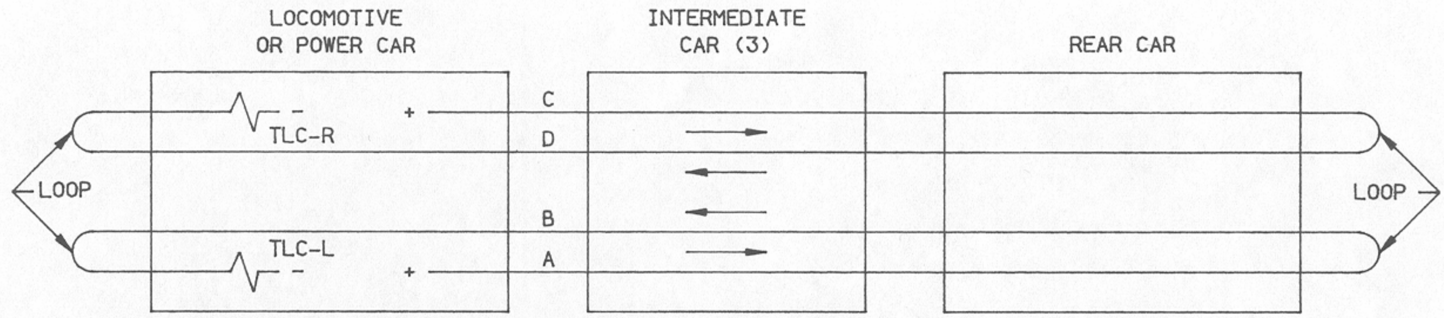


FIGURE:5 SIMPLIFIED TRAINLINE COMPLETE (TLC) OPERATION - TRAIN

NOTE: TLC IS TRAINLINE COMPLETE RELAY

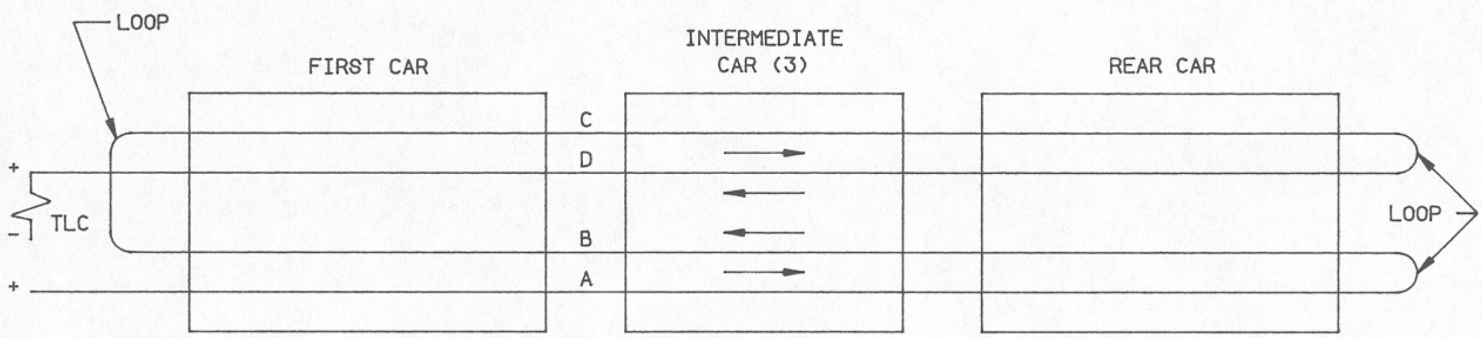
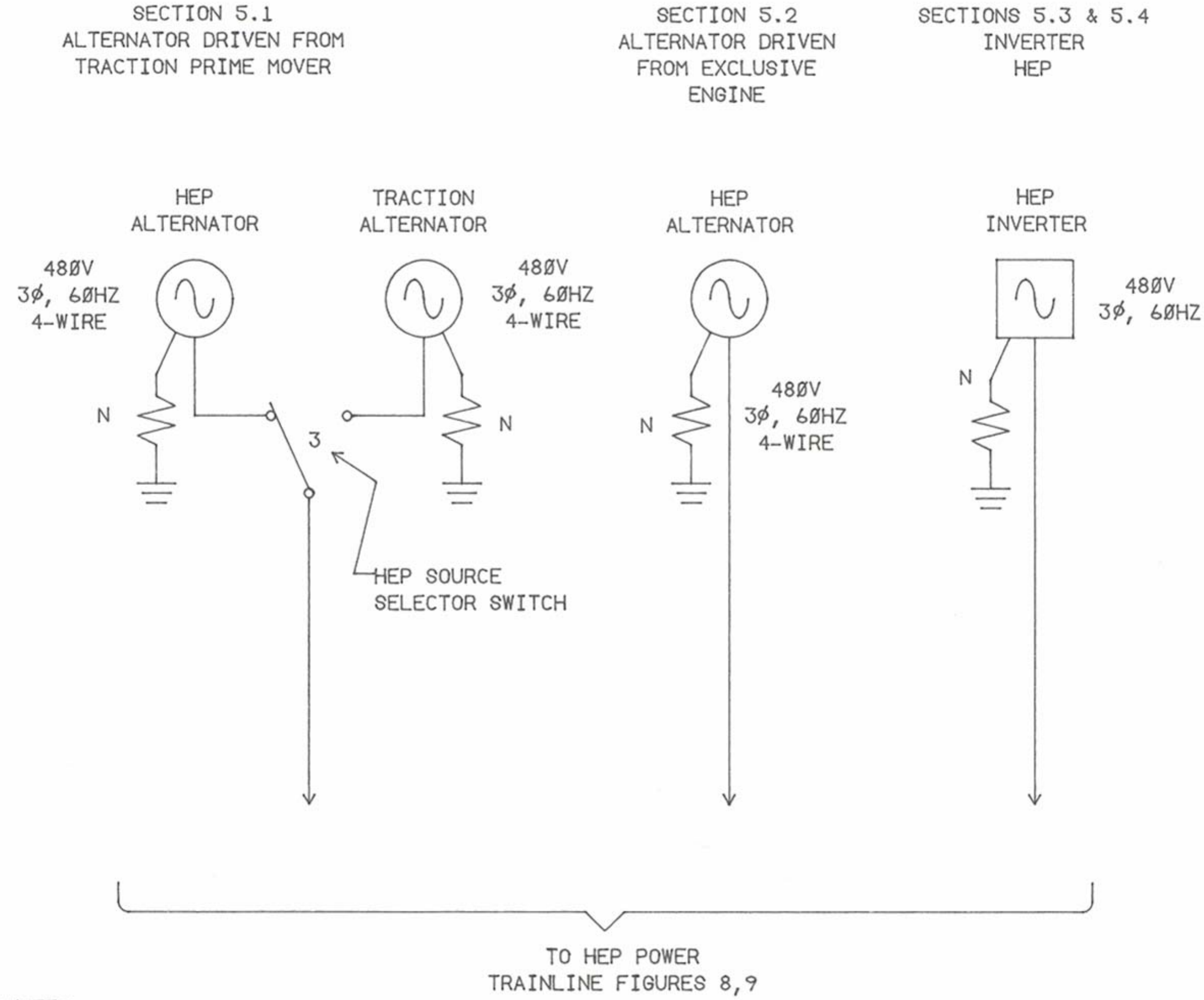


FIGURE:6 SIMPLIFIED TRAINLINE COMPLETE (TLC) OPERATION - WAYSIDE



NOTES
1. PHASE ROTATION = A,B,C

FIGURE 7
SINGLE - LINE SCHEMATICS
HEP SOURCES

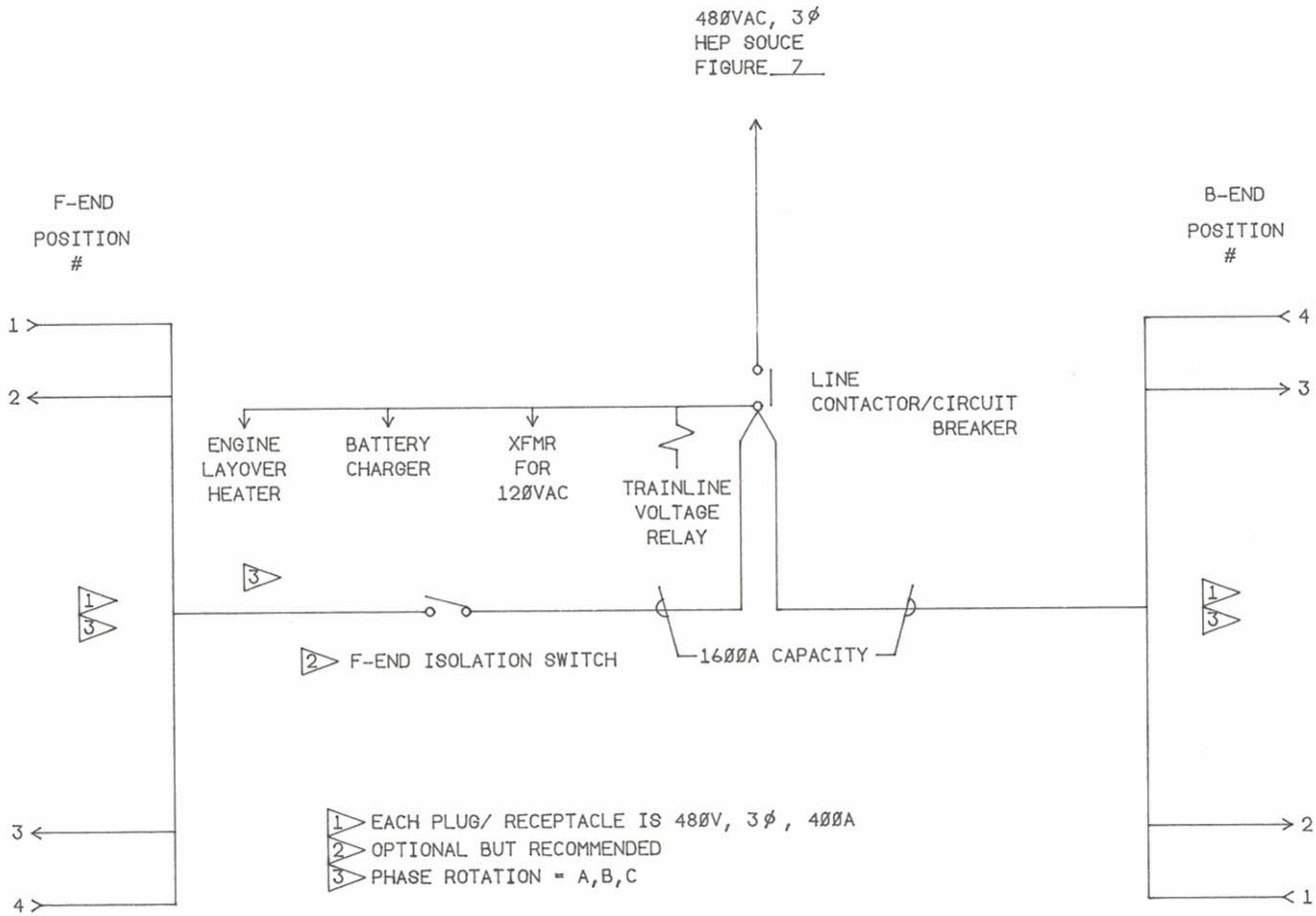


FIGURE 8
SINGLE-LINE SCHEMATIC:
SINGLE BUS
48ØV HEP POWER TRAINLINE

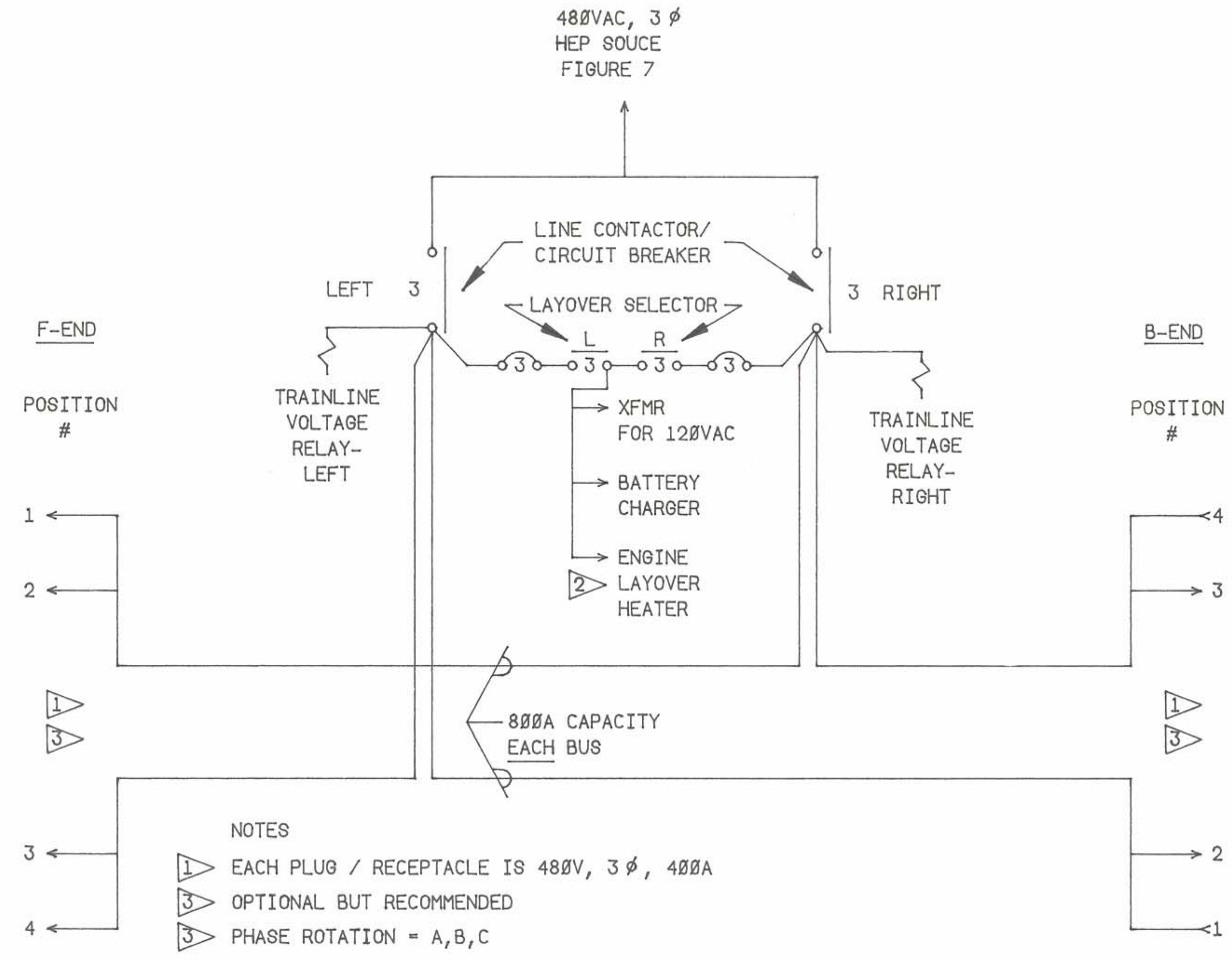


FIGURE 9
SINGLE-LINE SCHEMATIC:
SPLIT-BUS
480V HEP POWER TRAINLINE

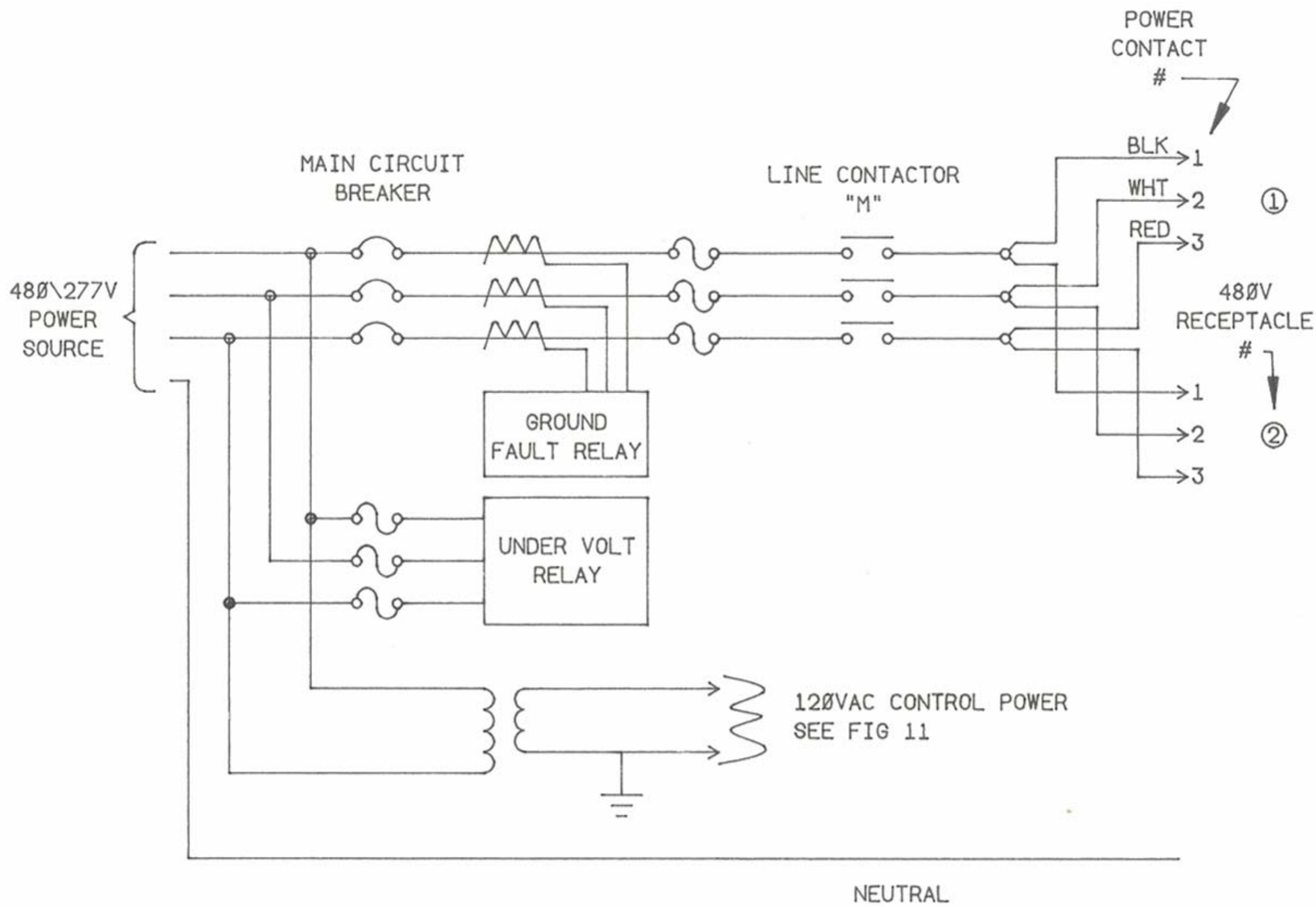
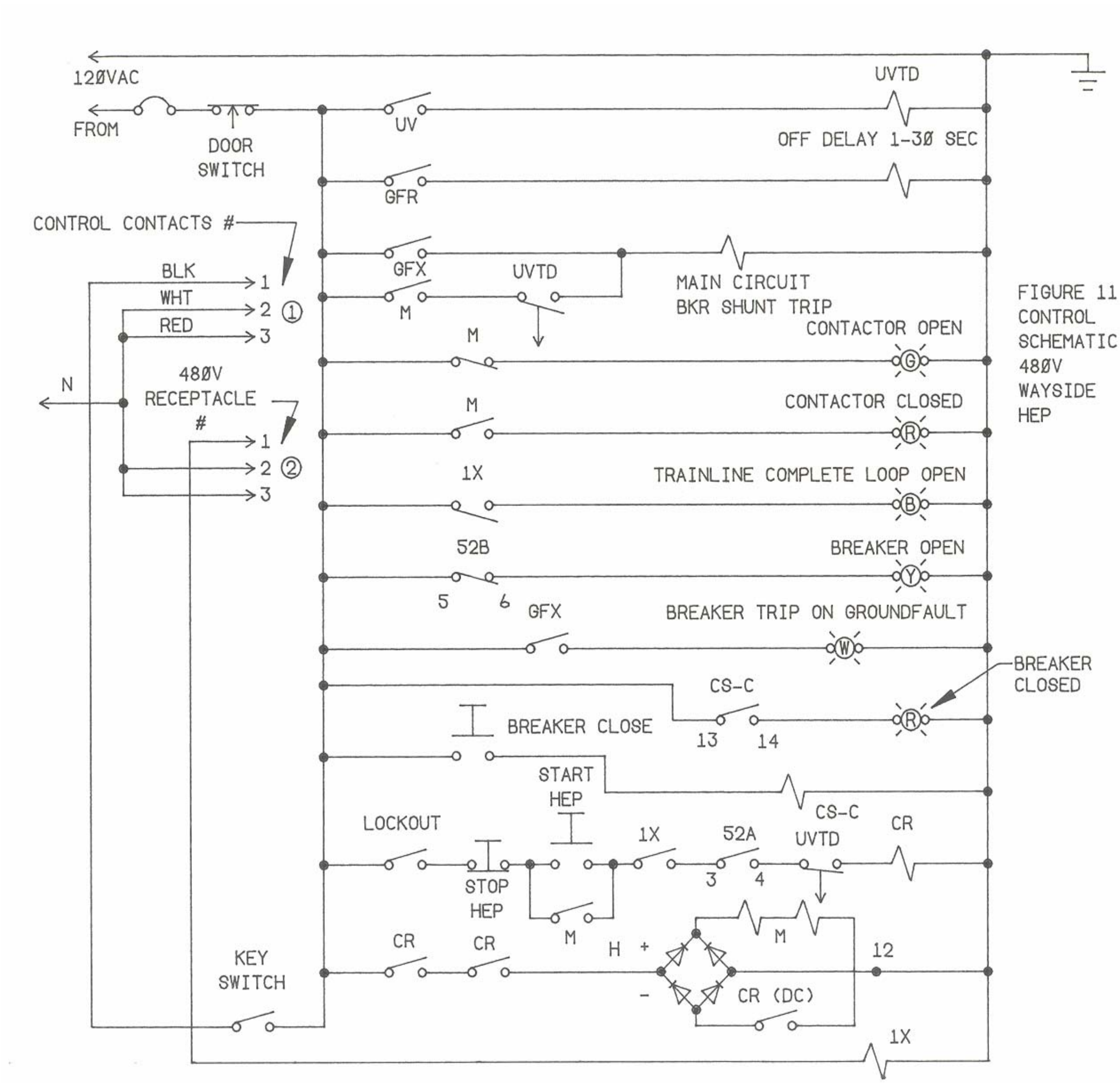


FIGURE 10
POWER SCHEMATIC: 480V WAYSIDE HEP


120ØVAC
FROM
DOOR
SWITCH
UV
UVTD
OFF DELAY 1-3Ø SEC
GFR
CONTROL CONTACTS #
GFX
UVTD
MAIN CIRCUIT
BKR SHUNT TRIP
BLK
WHT
RED
1
2
3
M
CONTACTOR OPEN
N
48ØV
RECEPTACLE
#
CONTACTOR CLOSED
TRAINLINE COMPLETE LOOP OPEN
1X
52B
BREAKER OPEN
5
6
GFX
BREAKER TRIP ON GROUNDFAULT
CS-C
BREAKER
CLOSED
BREAKER CLOSE
13
14
START
HEP
LOCKOUT
STOP
HEP
1X
52A
CS-C
UVTD
CR
3
4
M
CR
CR
H
+
-
CR (DC)
12
KEY
SWITCH
1X
FIGURE 11
CONTROL
SCHEMATIC
48ØV
WAYSIDE
HEP

APPENDIX A:

(infomative)

ITI (CBEMA) APPLICATION NOTE and CURVE

ITI (CBEMA) CURVE APPLICATION NOTE

The ITI (CBEMA) Curve, included within this Application Note, is published by Technical Committee 3 (TC3) of the Information Technology Industry Council (ITI, formerly known as the Computer & Business Equipment Manufacturers Association). It is available at http://.www.itic.org/technical/iticurv.pdf.

1) SCOPE

The ITI (CBEMA) Curve and this Application Note describe an AC input voltage envelope which typically can be tolerated (no interruption in function) by most Information Technology Equipment (ITE). The Curve and this Application Note comprise a single document and are not to be considered separately from each other. They are not intended to serve as a design specification for products or AC distribution systems. The Curve and this Application Note describe both steady-state and transitory conditions.

2) APPLICABILITY

The Curve and this Application Note are applicable to 120V nominal voltages obtained from 120V, 208Y/120V, and 120/240V 60Hz systems. Other nominal voltages and frequencies are not specifically considered and it is the responsibility of the user to determine the applicability of these documents for such conditions.

3) DISCUSSION

This section provides a brief description of the individual conditions which are considered in the Curve. For all conditions, the term "nominal voltage" implies an ideal condition of 120V RMS, 60Hz.

Seven types of events are described in this composite envelope. Each event is briefly described in the following sections, with two similar line voltage sags being described under a single heading. Two regions outside the envelope are also noted. All conditions are assumed to be mutually exclusive at any point in time, and with the exception of steady-state tolerances, are assumed to commence from the nominal voltage. The timing between transients is assumed to be such that the ITE returns to equilibrium (electrical, mechanical, and thermal) prior to commencement of the next transient.

3.1) Steady-State Tolerances

The steady-state range describes an RMS voltage which is either very slowly varying or is constant. The subject range is

+/- 10% from the nominal voltage. Any voltages in this range may be present for an indefinite period, and are a function of normal loadings and losses in the distribution system.

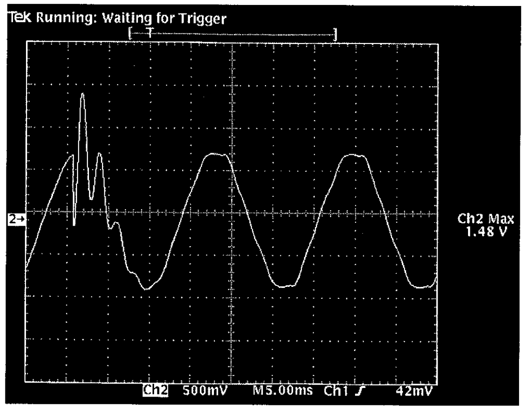
3.2) Line Voltage Swell

This region describes a voltage swell having an RMS amplitude of up to 120% of the RMS nominal voltage, with a duration of up to 0.5 seconds. This transient may occur when large loads are removed from the system or when voltage is supplied from sources other than the electric utility.

3.3) Low-Frequency Decaying Ringwave

This region describes a decaying ringwave transient which typically results from the connection of power-factor-correction capacitors to an AC distribution system. The frequency of this transient may range from 200Hz to 5KHz, depending upon the resonant frequency of the AC distribution system. The magnitude of the transient is expressed as a percentage of the peak 60Hz nominal voltage (not the RMS value). The transient is assumed to be completely decayed by the end of the half-cycle in which it occurs. The transient is assumed to occur near the peak of the nominal voltage waveform. The amplitude of the transient varies from 140% for 200Hz ringwaves to 200% for 5KHz ringwaves, with a linear increase in amplitude with increasing frequency. Refer to Figure 1 for an example of a typical waveform.

FIGURE 1



TYPICAL LOW FREQUENCY DECAYING RINGWAVE

3.4) High-Frequency Impulse and Ringwave

This region describes the transients which typically occur as a result of lightning strikes. Wave shapes applicable to this transient and general test conditions are described in ANSI/IEEE C62.41-1991. This region of the curve deals with both amplitude and duration (energy), rather than RMS amplitude. The intent is to provide an 80 Joule minimum transient immunity.

3.5) Voltage Sags

Two different RMS voltage sags are described. Generally, these transients result from application of heavy loads, as well as fault conditions, at various points in the AC distribution system. Sags to 80% of nominal (maximum deviation of 20%) are assumed to have a typical duration of up to 10 seconds, and sags to 70% of nominal (maximum deviation of 30%) are assumed to have a duration of up to 0.5 seconds.

3.6) Dropout

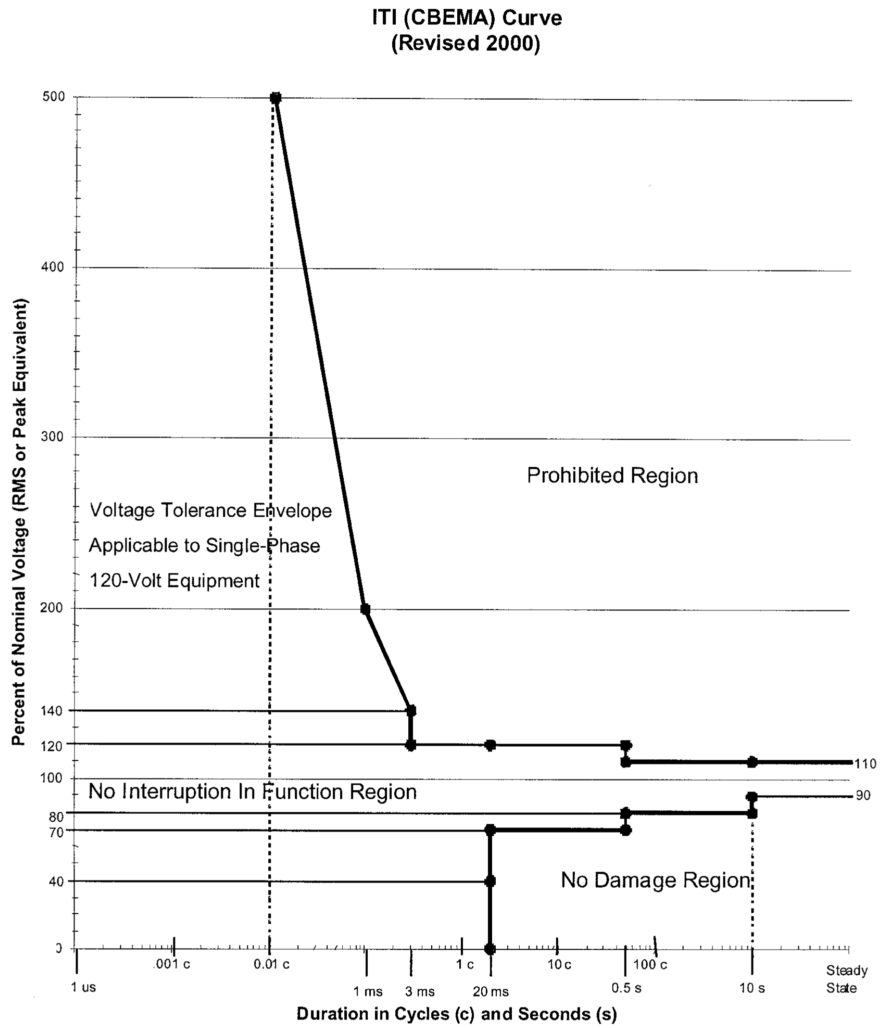
A voltage dropout includes both severe RMS voltage sags and complete interruptions of the applied voltage, followed by immediate re-application of the nominal voltage. The interruption may last up to 20 milliseconds. This transient typically results from the occurrence and subsequent clearing of faults in the AC distribution system.

3.7) No Damage Region

Events in this region include sags and dropouts which are more severe than those specified in the preceding paragraphs, and continuously applied voltages which are less than the lower limit of the steady-state tolerance range. The normal functional state of the ITE is not typically expected during these conditions, but no damage to the ITE should result.

3.8) Prohibited Region

This region includes any surge or swell which exceeds the upper limit of the envelope. If ITE is subjected to such conditions, damage to the ITE may result.



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