MOBILE DC POWER SYSTEMS FOR SUBSTATION APPLICATIONS

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Introduction

This paper explores the use of mobile DC power systems for three specific applications.

- Recovery from catastrophic battery and/or equipment failure.
- Performance and diagnostic tool for site battery/system maintenance and testing.
- DC System Redundancy for Site Loads

Mobile DC Power System Description Overview

Mobile DC Power Systems are typically engineered and equipped with battery chargers, batteries, AC/DC meters and controls including ancillary safety equipment in accordance with applicable IEEE Design and Installation Practices for Stationary Batteries and DC Systems as described in IEEE Std. 946 and IEEE Std. 446. Engineering mobile power system components with mechanical and electrical isolation capability allows the user to suspend system operation for safety and maintenance purposes.

Depending on DC load requirements, provisions are made to offer systems in single or multiple DC output voltage configurations. For example, nominal 48VDC and 120VDC mobile power systems offer versatility to service substations operating on one or both dc voltages. The 48VDC supply may be accomplished via a dedicated 48V battery and charger or by means of a 120V to 48V DC to DC Converter. Please refer to Figure 1 depicting a typical mobile DC power system.

Mobile power systems are often equipped with ac power generators to provide a dedicated input power source where commercial utility power may not be available. Generators provide input power for the entire system including battery chargers and other ac powered equipment used during black start, commissioning or in the event of a total ac station power failure.

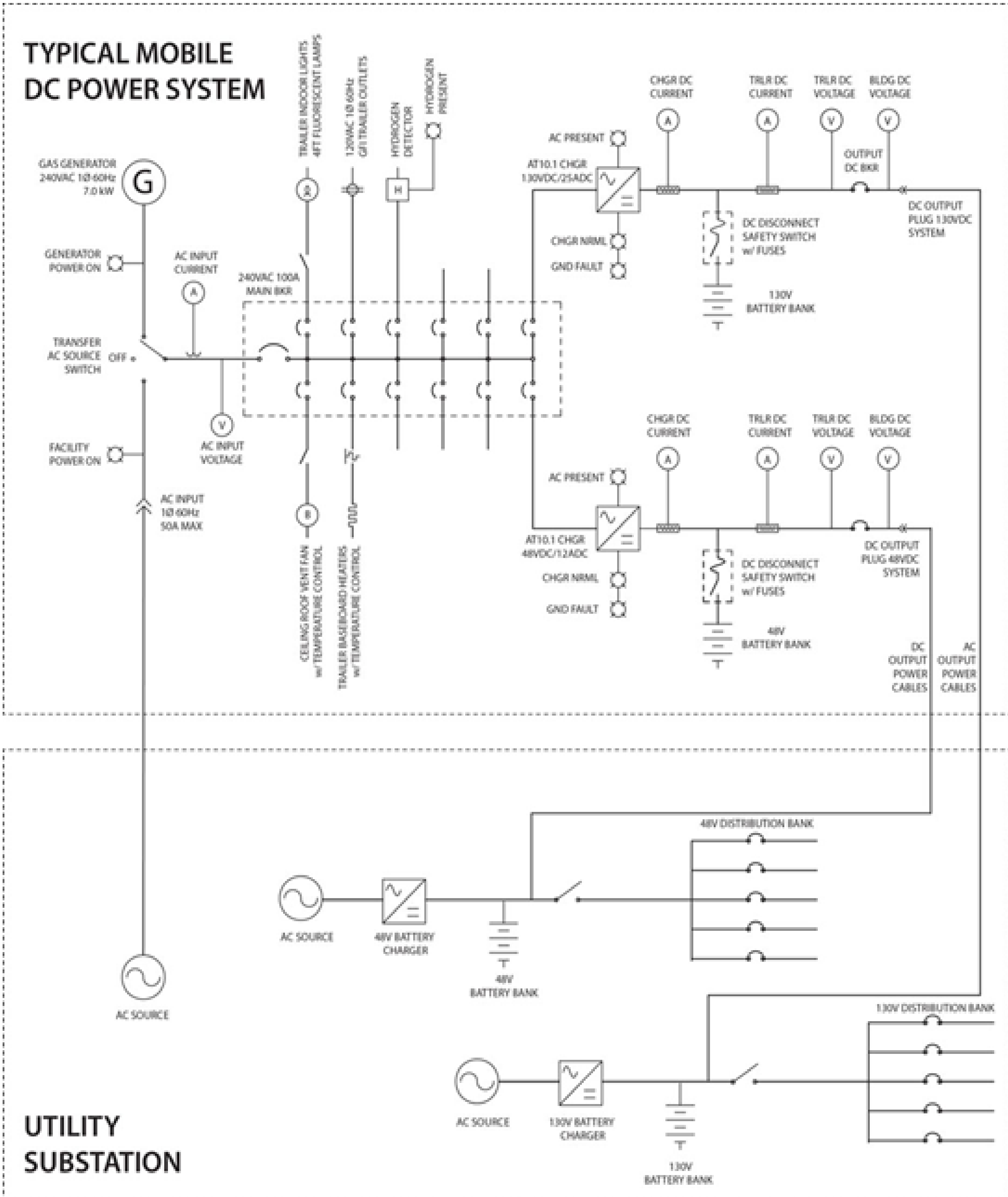

Figure 1. Utility Substation

Primary Mobile DC Power System Component Description and Function

Batteries: Acting as the heart of the entire system, batteries play a critical role as a back-up power source for lost or interrupted station power. They assume the function of the existing station battery for both transient (i.e. breaker trip and oil pump function in substations) as well as assuming constant equipment loads (i.e. switchgear and communications) in the event of an ac power outage leading to battery charger failure.

Careful consideration should be given to the battery selection to ensure not only electrical performance but also to the mechanical/structural design to allow optimal handling and provide desired design life. Batteries used in these applications may be subjected to a degree of shock and vibration as well as temperature excursions, well beyond what is typically encountered in stationary applications, while the trailer system is in use.

There are a multitude of battery chemistries and configurations available. However, two specific battery types, Valve-Regulated Lead Acid (VRLA) and Nickel-Cadmium (NiCad), offer several unique advantages.

VRLA Batteries are well suited for mobile power system applications. They are typically more space efficient, easier to install, require less maintenance and are relatively lower in cost compared to most other battery types. Their internal construction consisting of a micro-porous fiber plate wrap offers a higher level of shock and vibration protection (versus standard VLA type batteries) while the trailer is in transit.

However, VRLA battery design offers a few disadvantages. Their performance and life are more dramatically affected by changes in temperature than their wet-cell counterparts. Higher operating temperatures lead to potential adverse conditions such as cell dry-out where non-compensated charging results in excessive hydrogen evolution and loss of water. In addition, typical VRLA multi-cell mono-bloc type batteries, commonly found in these applications, may not offer desired cycle life leading to more frequent battery replacement.

NiCad Batteries offer a rugged mechanical design where periods of shock and vibration are common during trailer transportation to and from the intended site. Also, NiCad Batteries experience minimal performance degradation in environments with potentially large differentials in ambient and/or operational temperatures often associated with these applications. This is particularly true where climatically controlled devices are inoperative or not available. Finally, NiCad Batteries are able to electrically recover back to their nameplate capacity and operational cell voltages after deep discharge or from depleted capacity due to extended periods on open circuit.

The type of battery used in mobile applications should be carefully considered based on a number of criteria such as station duty profile, expected operating temperature conditions and desired design life. Wet vented lead-acid (VLA) batteries are not recommended for mobile applications. Although they offer many performance advantages versus VRLA design, they contain free liquid electrolyte that may spill or leak during times of transporting trailers to/from a site. Electrolyte contact could result in equipment and/or environmental damage. Both DOT and EPA regulations must be considered whenever batteries are employed as part of a DC system. See “Battery Safety Equipment” regarding the importance of battery spill containment.

As mentioned earlier, the trailer may be exposed to a degree of shock and vibration while in transit. Therefore, a properly designed mechanical restraint system should prevent both horizontal and vertical battery movement. Flexible inter-cell cable connectors are recommended to minimize potential battery post connection stress and reduce the risk of post or seal damage.

Battery Chargers: The battery charger functions as the primary DC power source for maintaining battery float voltage and providing current to continuous dc station loads. For trailer applications where VRLA batteries are used, it is highly recommended that chargers are equipped with an option allowing a temperature compensated charging algorithm. This feature allows the charger to automatically adjust its output voltage based on actual battery temperature. Temperature compensation helps ensure proper charge voltage and promotes intended battery life.

Electrical Connections and Safety: Several factors should be considered regarding physical connections to the mobile system, as referenced in IEEE Std. 1375. Essentially, this is an outdoor application. To ensure the integrity of both the AC and DC power connections, in accordance with applicable NEMA Standards, water-tight, twist-lock type connections are ideal to guard against short circuits and potential shock hazard due to ingress of moisture or wind-driven rain and snow. Both AC input and output DC circuit breakers protect the mobile system from electrical faults and provide a means of turning the system on or off.

AC Power Generator: Offer a dedicated AC power source, particularly in applications where input utility power is not available. Generators provide input power to a circuit breaker panel where it's distributed to the battery chargers and receptacles used for powering other ancillary equipment (i.e. battery monitoring devices, hydrogen sensors, interior lighting and/or HVAC), as required.

Meters/Control/Annunciator Panels: It is crucial for the operator to be able to properly monitor the mobile DC system on both the ac and dc side of the application. Annunciator panels provide power diagnostics related to I/O voltage and current as well as alarms to identify any potential system faults. Pinpointing system faults allow corrective action to be taken quickly to eliminate potential harm to both the mobile power system or station equipment connected to it.

The Annunciator panel design includes the use of weather-proof, twist-lock receptacles for making AC and DC power cable connections. These connectors help ensure proper contact and guard against moisture and wind-driven elements from interfering with electrical connections that could lead to system faults. As a further measure of electrical protection, input and output circuit breakers minimize the threat of potential short circuit or high in-rush currents originating from station equipment that could lead to equipment damage.

Hydrogen Detection/Alarms and Mitigation: As with any power system, using stationary batteries as part of the circuit, good industry practices recommend the use of hydrogen detection equipment. These devices are designed to alert the operator of unacceptable levels of hydrogen evolution. Detectors equipped with alarm relay contacts provide a means of reducing hydrogen levels by initiating exhaust fans, forcing excess hydrogen from the point of origin. In conjunction with initiating fan operation relay contacts wired to the battery charger may be programmed to shut the charger down once a hydrogen threshold has been reached.

Further assisting forced air ventilation, passive type roof vents provide a further degree of hydrogen mitigation.

Electrical-Mechanical DC Protection: U.L. Listed DC Disconnect Switches offer a degree of flexibility by providing a variety of uses in mobile power systems. Primarily, DC Disconnects isolate the battery to conduct recommended maintenance, conduct battery testing procedures and cell replacement. These devices also provide a degree of protection from short circuit current interruption.

Battery Safety Equipment: Maintaining a safe work environment, in accordance with applicable OSHA requirements, is just as critical in a mobile DC power system as it is in a control building or battery room where batteries are used and personnel are present. Easy access to industry accepted eye-wash stations and spill containment are important for applications where batteries contain free electrolyte. These systems include neutralization and proper disposal in accordance with local, state and federal DOT Regulations as well as applicable OSHA Standards and Practices for Stationary Batteries.

Battery Monitoring and Load Testing: Understanding the health of the applied battery is essential to ensure it will perform as intended. Mobile power systems equipped with load bank and monitoring equipment allow operators to test the existing battery and assist in identifying potential performance and/or capacity issues.

Mobile DC Power Connection to the Substation

There are several methods for making physical AC and DC power connections from the mobile power system to the substation.

AC power cables are sized in accordance with NEC practices and are calculated based on ampacity and distance to the substation connection point. Connection to the mobile power system is made via NEMA standard weather-proof, twist-lock, shore power type connectors. The station end of the cable is typically connected to the substation via one of three common user-specified connector styles including:

- Non-terminated connection where cable is "bugged" into the ac feed.
- Screw-type lug connectors
- Mueller Clamp connectors

Color coded positive and negative polarity DC power cables are sized in accordance with user specifications. Connection to the mobile power system is made via weather proof, twist lock type connectors. DC cables should be rated for the maximum station load, taking voltage drops into account. As with the AC power cables, the station end of the DC power cables connect via one of the three type user-specified connections styles listed above.

Substation Power Docking Station: To facilitate a standard connection point to a number of sites, docking stations allow operators to connect in a consistent fashion and eliminate the need to provide a variety of connectors. The docking station is typically an externally mounted NEMA 3R rated enclosure with AC and DC power termination points pre-wired to the substation. Docking stations equipped with transfer switches or steering diode assemblies permit switching and isolation between substation power and mobile power for maintenance or black start applications. Communication to the docking station via SCADA alarm connection provides system diagnostic alarms and alerts users of potential system faults or performance issues.

Application #1: Catastrophic/Disaster Recovery/Black Start

During a catastrophic battery and/or equipment failure, mobile power systems should be engineered and designed for swift deployment to quickly restore site power and resume normal operation while site issue(s) are diagnosed and repaired. Disaster recovery time is greatly reduced by providing a system "on demand."

Application #2: Battery and DC System Maintenance

As a maintenance tool, mobile power systems act as a temporary power source for conducting site maintenance and testing. As industry demands for greater reliability increase, mobile power systems offer a means to carry out critical procedures and verify the system potential performance in accordance with NERC standards and the operator's reliability plan.

Mobile power systems equipped with load banks offer the ability to test substation battery performance and capacity. These tests may be performed off-line while maintaining power to the site. Measuring and recording battery performance through the use of battery monitoring equipment identifies potential battery issues that require immediate attention.

Application #3: Redundancy

Mobile DC power systems offer a level of redundancy required where interruption of critical loads and system operation cannot be compromised. Connecting these systems into the station circuit using a steering diode assembly allows the existing loads to select the DC power source with the highest potential in applications involving parallel battery plants. This application ensures site loads remain operational, minimizes risk and greatly increases system reliability.

Summary

Mobile DC Power Systems offer user flexibility as either a back-up or redundant power source. They also serve as invaluable tools to facilitate proper DC power station maintenance. However, for these mobile systems to work safely and effectively, sound engineering practices must be followed in their design and operation. In addition, proper maintenance and testing of the mobile dc power system should be conducted per IEEE Std. 450 and NERC PRC-005 requirements to assure design performance and reliability.

References

IEEE Std. 946. IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Systems.

IEEE Std. 446. IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications.

IEEE Std. 1375. Guide for the Protection of Stationary Battery Systems.

IEEE Std. 450. IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.

NEMA Standards Publication PE 5. Utility Type Battery Chargers.

OSHA Standard 1925.403

NERC Standard PRC-005 (latest draft)

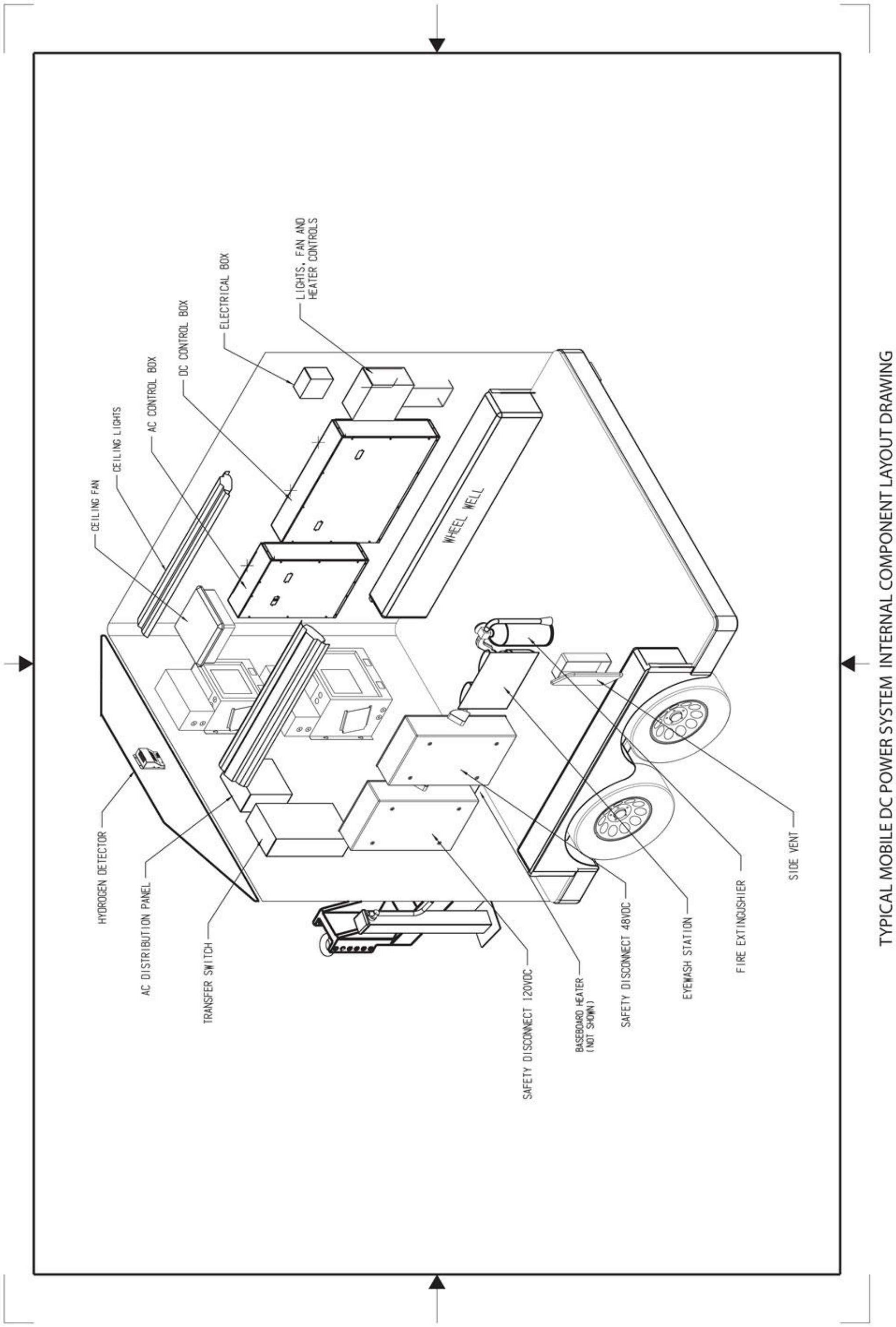

Figure 2. Typical Mobile DC Power System Internal Component Layout Drawing

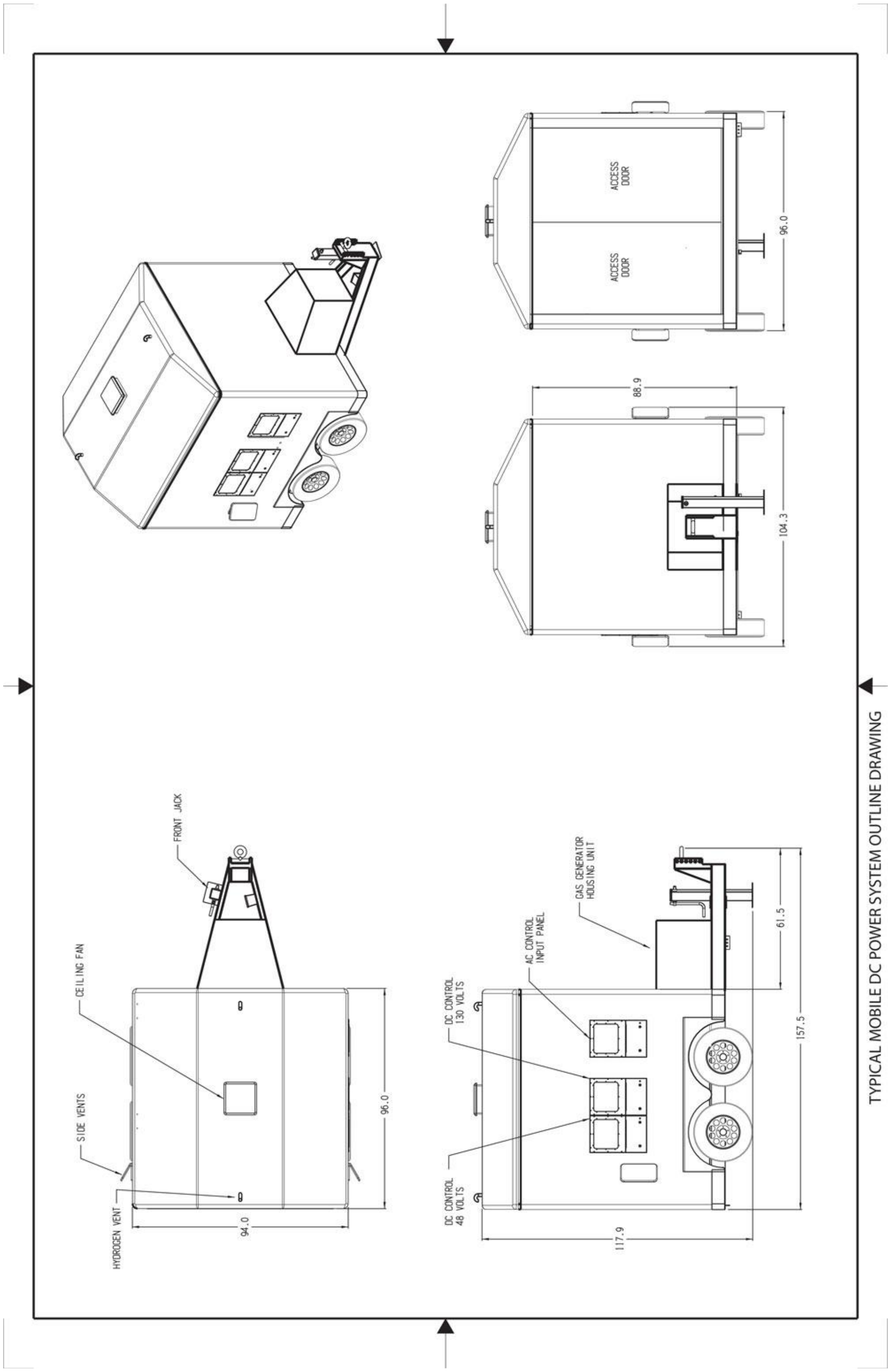

Figure 3. Typical Mobile DC Power System Outline Drawing