



IEEE Standard for DC Microgrids for Rural and Remote Electricity Access Applications

IEEE Power and Energy Society

Developed by the
Transmission and Distribution Committee

IEEE Std 2030.10™-2021

IEEE Standard for DC Microgrids for Rural and Remote Electricity Access Applications

Developed by the

Transmission and Distribution Committee
of the
IEEE Power and Energy Society

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IEEE SA Standards Board

Abstract: The design and operation of a dc microgrid for rural or remote applications based on extra low voltage dc (ELVDC) to reduce cost and simplify stability are discussed in this standard. Such microgrids are typically operated without connecting to a nation's electric power system.

Keywords: ELVDC, extra low voltage, IEEE 2030.10™, microgrid

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Introduction

This introduction is not part of IEEE Std 2030.10-2021, IEEE Standard for DC Microgrids for Rural and Remote Electricity Access Applications.

This standard defines microgrids for rural and remote locations that normally operate with intermittent or no connections to a nation's primary ac grid. The components in this architecture utilize extra low-voltage dc (ELVDC) to reduce costs and simplify stability.

This standard harmonizes with ISO 21780:2020 for road vehicles with a 48 V supply voltage.¹ The intent of this harmonization is twofold: it permits appliances and other devices compatible with this standard to be powered using a vehicle's 48 V auxiliary power outlets, and it also permits the reuse of 48 V electrical components designed for use in vehicles. ISO 21780:2020 contains device categories and functions that are specific to vehicles. Some of those distinctions are not relevant to appliances and devices when used outside of a vehicle so this standard only addresses distinctions that would be useful both outside and within a vehicle while insuring compatibility for use on both environments. At a high level, the goal is to reduce the fragmentation of incompatible 48 V appliances with a standard that permits manufactures to sell conforming products to a broader customer base than just rural microgrids.

This standard consists of two parts. The first part specifies normative requirements and defines the operating parameters for components used to construct the microgrid. These requirements are intended to enable conforming microgrids to be constructed from components with minimal constraints. The second part, comprising the bulk of the document, consists of recommendations addressing the practical concerns needed to design and operate such a microgrid. These include important safety suggestions.

The intent of this standard is to define a microgrid that can be constructed from components that exist in the marketplace rather than new components purposely designed for the standard. Using purpose-built dc-dc converters, for example, to source microgrid power could improve the flexibility and scalability of the microgrid but could also involve complex technical problems in managing microgrid stability. This standard is intended to serve as springboard for future revisions that may address those problems and help allow more sophisticated dc microgrids to be constructed.

Many aspects of a dc power system are not addressed by this standard. It does not address wiring and distribution inside a home or building, nor the appliances that use grid power except to establish voltage and power quality expectations for those appliances in the absence of point-of-load converters or local energy storage. Similarly, details of dc power sources such as photovoltaic (PV) panel, charge controller, and battery wiring are not addressed though references are provided for other standards that do address these issues. The standard does not address operational issues such as billing. The standard depends on voltage observation for managing load and does not propose a communications protocol to shed loads as the microgrid in this standard is intended to operate passively, without an intelligent microgrid controller. The possibility of disconnection based on observed voltages using contactors is described but there are no specific requirements in the standard. Combining customer power generation via a solar home system, for example, with microgrid power is mentioned but implementation details are not addressed. The possibility of sourcing power from a national grid using a rectifier is mentioned but the details of such a connection are not addressed. Bidirectional connection of batteries so they can be recharged from the microgrid is mentioned but the standard does not impose related requirements.

¹ Information on references can be found in [Clause 2](#).

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WARNING

DC microgrids involve significant risks of serious injury if not properly designed, operated, and maintained. This standard is intended to provide technical information only to persons who have sufficient expertise and experience to appreciate the safety issues involved in the design, operation, and maintenance of dc microgrids, and is not intended to identify, appraise, or evaluate all risks. Adherence to the standard is not a guaranty of safety, and the IEEE expressly disclaims any warranty of safety in connection with this standard.

1. Overview

1.1 Scope

This standard covers the architecture of a dc microgrid for rural and remote applications with a nominal distribution voltage of 48 V. It defines voltage and power quality metrics for power supplied to loads attached to such a microgrid. This standard focuses on the power distribution portion of a microgrid and addresses sources only in the way that they are attached to the grid. It does not impose either minimum or maximum current limits.

Users of this standard are responsible for observing all applicable laws and regulations related to power grid and microgrid design, operation, and maintenance. Compliance with the provisions of this standard does not imply compliance to any such legal or regulatory requirements.

1.2 Purpose

The purpose of this standard is to address the needs of the electrical power industry to provide access to electricity in areas where a national grid infrastructure may not be available. DC microgrid applications can also provide power where infrastructure costs or other issues prohibit connection to the national grid even in places where a national grid is available. This standard provides the framework to allow for deployment of distributed generation, storage, and use of electricity based on identified requirements and existing technology. Further, it has the goal of facilitating the use of clean renewable generation of electricity in these applications.

The most important use of these microgrids is to supply electricity to people in remote locations without access to the primary ac grid. Low cost and safety are critical. Simplicity and reliability are important to their needs as well.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{2, 3}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ISO 21780:2020, Road vehicles—Supply voltage of 48 V—Electrical requirements and tests.⁴

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁵

arc: A plasma bridge formed in a gap between two electrodes with sufficient potential difference, often accompanied by sparks.

busbar: A metallic strip or bar used inside power distribution equipment to transfer high currents.

catenary: The curve that an idealized cable or chain assumes under its own weight supported only at the ends, superficially similar to a parabola but actually a different mathematical function.

common-mode choke filter: Series in-line transformer used to mitigate common-mode current flow without affecting differential current flow.

contactor: An electrically controlled switch used for repeatedly establishing and interrupting an electric power circuit.

² The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

³ The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

⁴ ISO publications are available from the International Organization for Standardization (<http://www.iso.org/>) and the American National Standards Institute (<http://www.ansi.org/>).

⁵ *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

cross-contact: The accidental contact between dissimilar electrical systems such as one of the poles of the low-voltage dc grid and an ac hot wire.

dc-dc converter: A device or system for isolating and/or for changing dc at one voltage to dc at a different voltage.

droop curve: A graph of voltage as a decreasing function of power for a power source used to determine the operating point and balance currents when multiple power sources are connected in parallel.

earth fault: An unintended connection between an energized conductor and the earth or another conductor such as a safety conductor, enclosure, or chassis that is deliberately connected to earth.

electronic fuse: A semiconductor device used to limit current during fault conditions similar to a thermal fuse but capable of being electronically reset.

electromagnetic compatibility: The condition that prevails when devices or networks perform their individually designed function in a common electromagnetic environment without causing or suffering unacceptable degradation due to electromagnetic interference to or from other equipment in the same environment.

fire: Self-supporting combustion that spreads, uncontrolled, with time, and in space, and may result in bright light, heat, smoke, burning, or a combination of all the above. (Adapted from ISO 21780:2020)

NOTE—Information on references can be found in [Clause 2](#).⁶

flyback diode: A diode connected across an inductor used to eliminate flyback, the sudden voltage spike seen across an inductive load when the inductor's current is suddenly reduced or interrupted.

gas discharge tube: A device consisting of a discharge gap between two or more electrodes hermetically sealed in a ceramic or glass envelope containing a gas, used for surge protection, illumination, or other purposes.

ground fault: *See:* earth fault.

Hall-effect probe: A magnetic flux density sensor containing an element exhibiting the Hall-effect to produce a voltage proportional to the magnetic flux density.

maximum power point tracking (MPPT): A technique used to extract the maximum power from a photovoltaic panel or other power source by continuously adjusting the input impedance of a converter so that operating point of the source's current-voltage curve stays at its maximum power despite changing conditions of illumination, temperature, and load.

metal oxide varistor (MOV): An electronic component whose electrical resistance varies with its applied voltage commonly used for surge protection.

microgrid: A group of interconnected loads and distributed energy resources with clearly defined electrical boundaries that act as a single controllable entity with respect to the grid that may connect and disconnect from the grid to enable it to operate in both grid-connected or island modes.

NOTE—The IEEE definition of a microgrid as given in other standards such as IEEE Std 2030.7TM assumes an ac microgrid that is normally connected to the national grid. This definition clarifies that the microgrid may or may not have a connection to the national grid.

⁶ Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

protected extra low voltage: A circuit, operating at 60 V dc or below, in which one of the poles is connected to earth.

sag: The distance measured vertically from a conductor to the straight line joining two points of support. Unless otherwise stated, the *sag* referred to is at the midpoint of the span.

separated extra low voltage (SELV): A circuit, operating at 60 V dc or below, with both poles isolated from earth.

service drop: The wiring from the grid point of attachment to the customer premises.

span: The distance measured horizontally between the supports of a conductor.

touch-safe: An energized surface that can be touched by humans without injury under normal, dry operating conditions.

3.2 Acronyms and abbreviations

ACSR aluminum conductor, steel reinforced

ELVDC extra low voltage dc

NOTE—Sources differ on the definition. IEC 60038 defines it as less than 120 V dc. Other sources define it as less than 60 V dc.

HDPE high-density polyethylene

MOSFET metal-oxide semiconductor field-effect transistor

MOV metal oxide varistor

MPPT maximum power point tracking

PELV protected extra low voltage

PV photovoltaic

PVC polyvinyl chloride

SELV separated extra low voltage

4. System architecture

4.1 Architecture overview

Any grid, including microgrids, can be partitioned into power sources, power distribution, and power application that deliver power within a home or business to lighting, appliances, and other uses. (See [Figure 1](#).) The requirements of this standard apply to the portion between the source attachment and the service distribution.

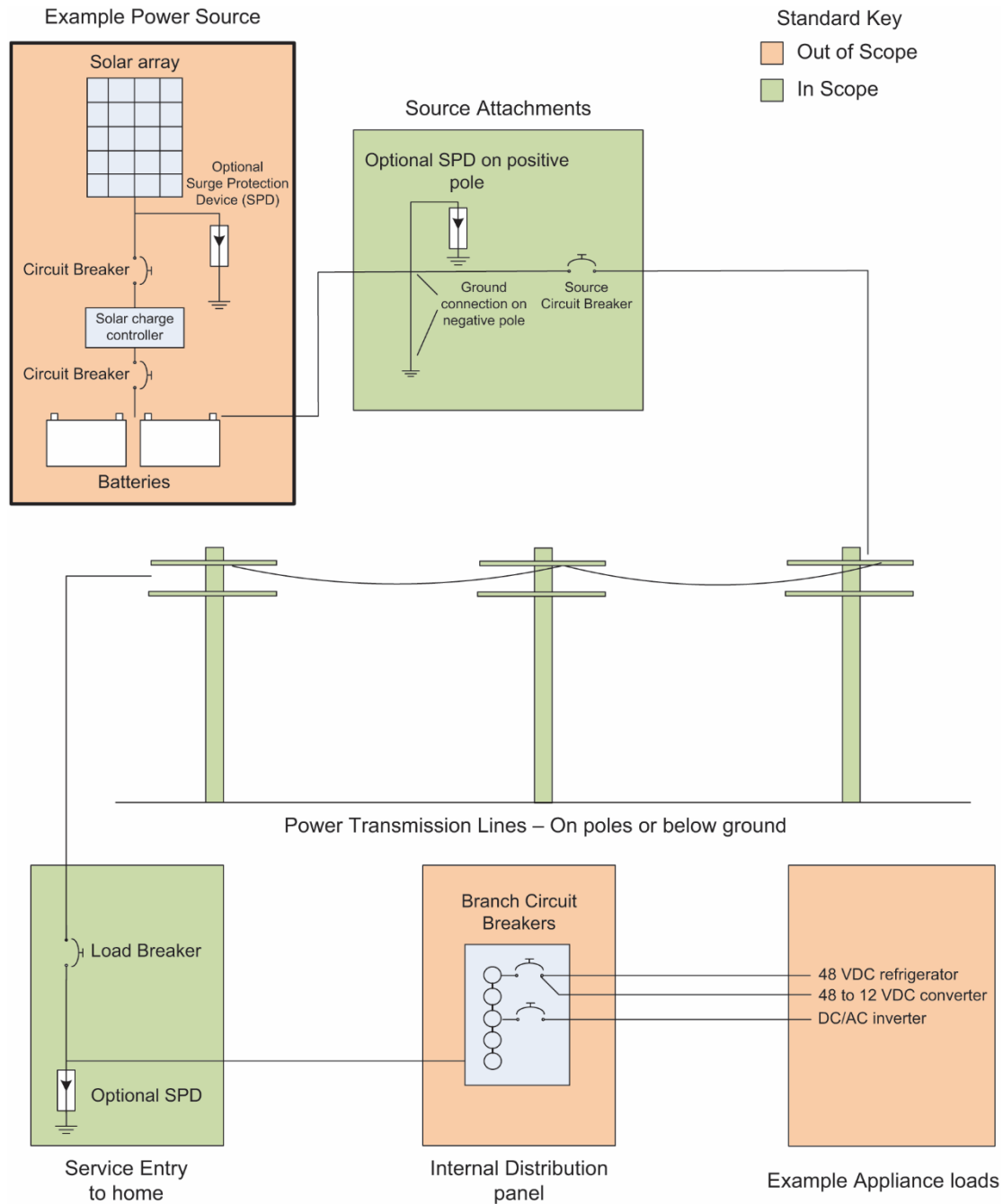


Figure 1—Basic microgrid architecture

This standard assumes that the most commonly used power source for this application will be photovoltaic (PV) panels but does not preclude other sources such as wind power, micro-hydro, fossil-fueled generators, energy storage systems, or even intermittent connection to a national grid with ac converted to dc via a rectifier. It further assumes that the sources will be intermittent, so batteries are used to store and deliver power when the load demand exceeds the available generated power.

In the most common configuration, PV panels are the primary power source. Power is delivered through a charge controller to a battery bank when the sun is shining. The details of the PV panel to charge controller wiring are outside the scope of this standard and implementers are responsible for conforming to the

requirements of the local authority having jurisdiction for PV wiring. Likewise, the specifics of the charge controller depend on the type of batteries in use and need to conform to existing standards. This standard focuses on the wiring and associated components between the batteries and the service entry where grid power enters the building.

More generally, the microgrid may consist of multiple power sources of varying types and similarly a variety of loads with different characteristics. (See Figure 2.) When there are multiple source connections, special provisions may be needed to balance the current between the sources (see A.9.3 and A.10.2), and if the sources incorporate dc-dc converters, the converters shall be designed to be stable under all permitted loads (see A.10.1).

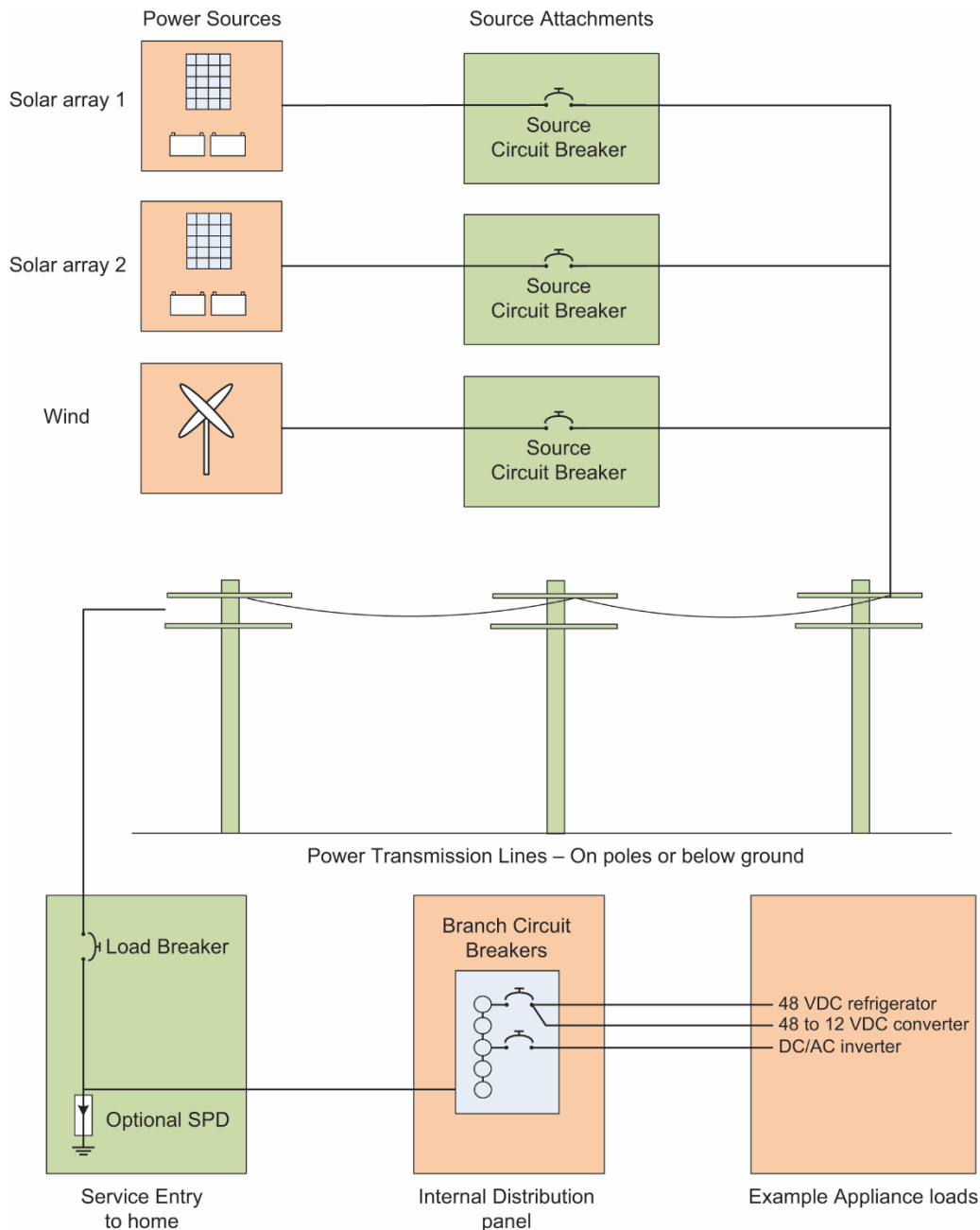


Figure 2—Microgrid with multiple power sources