



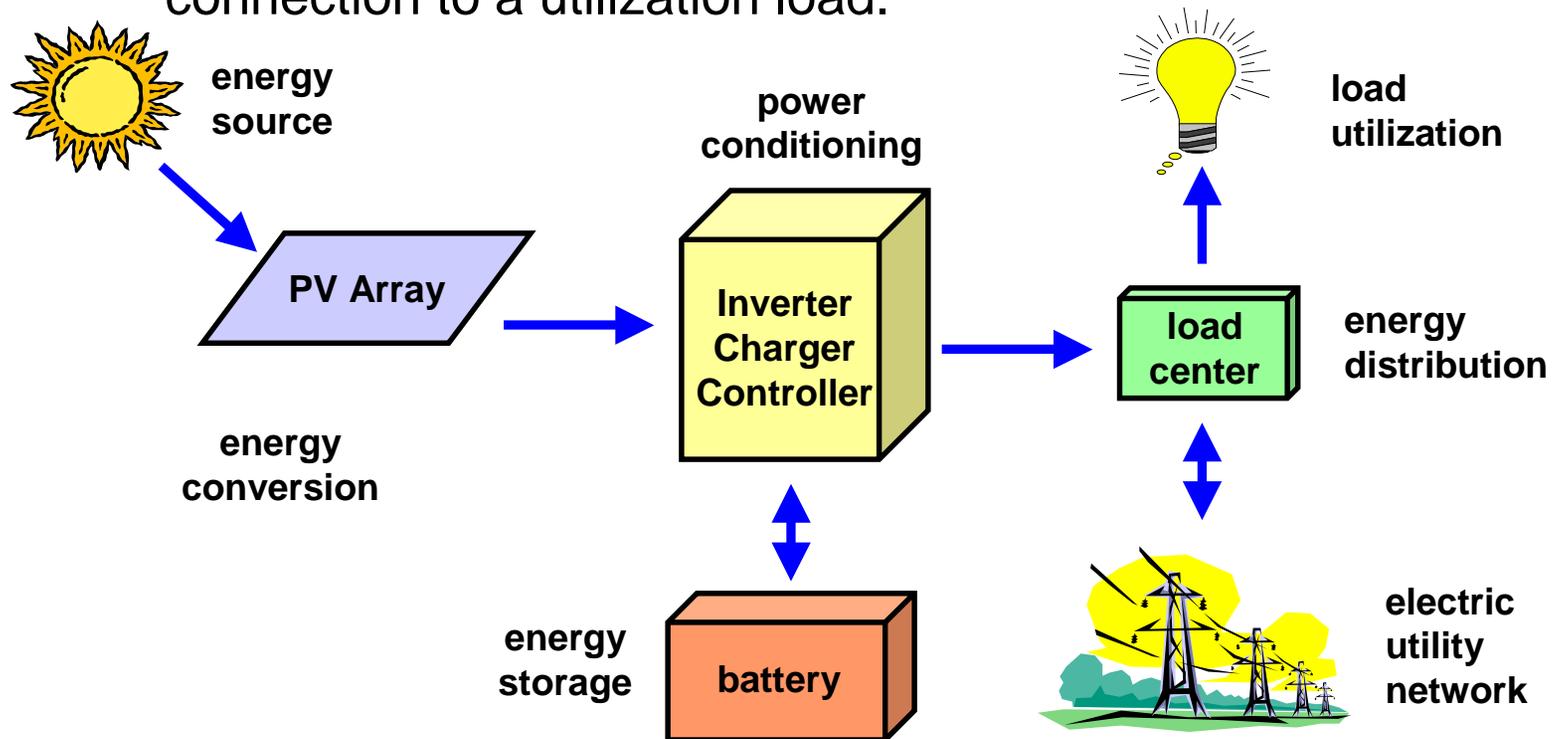
Solar Photovoltaic Systems and Components



Solar Photovoltaic System (SPS)

◆ Solar Photovoltaic System (690.2)

- The total components and subsystems that, in combination, convert solar energy into electrical energy suitable for connection to a utilization load.





Solar Photovoltaic System (SPS) Components

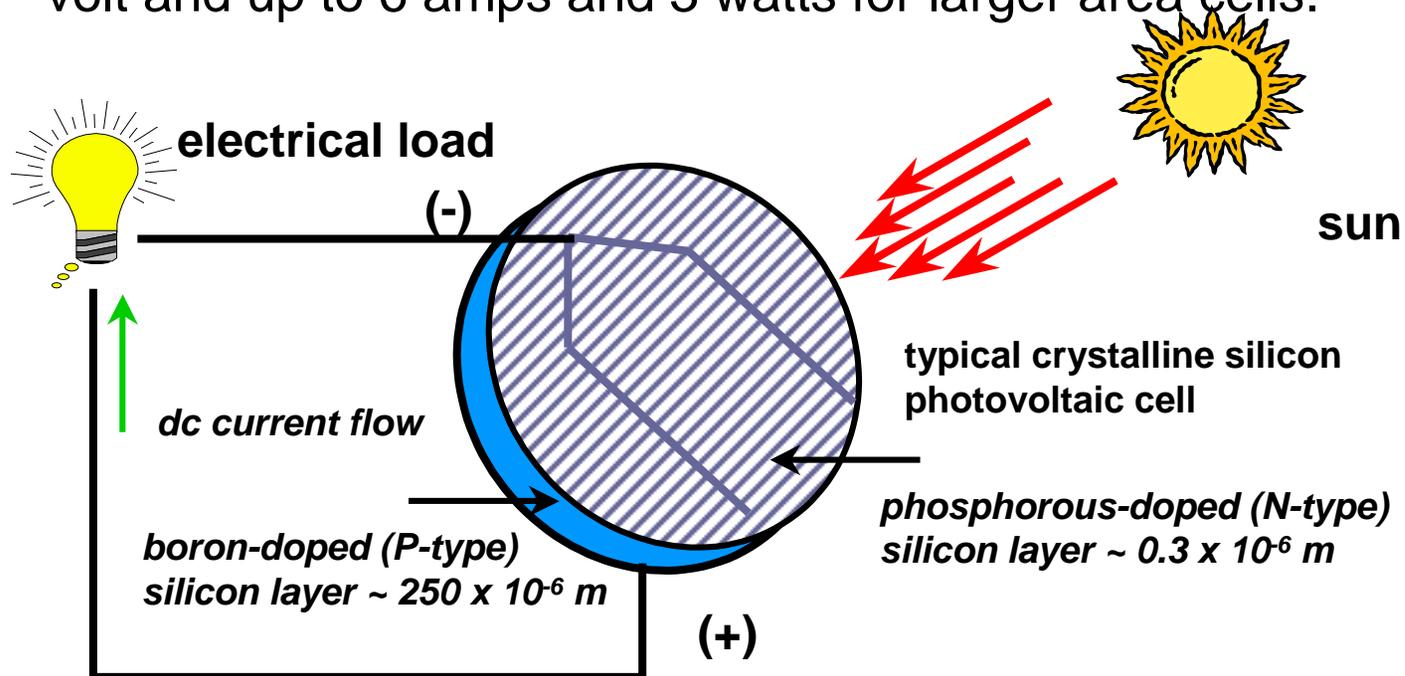
- ◆ **PV Array:** An electrical assembly of photovoltaic modules that convert sunlight to DC electricity.
- ◆ **Inverter:** A device that converts DC power from batteries or PV arrays into utility-grade AC power.
- ◆ **Energy Storage:** Electrical or other storage devices sometimes used to store energy produced by PV arrays for later consumption.
- ◆ **System Charge Control:** A device used to protect batteries from overcharge and overdischarge, sometimes provide load control functions.
- ◆ **Load:** Energy consuming electrical appliances served by the system.
- ◆ **Balance of System (BOS) Components:** Other equipment required to control, conduct, protect and distribute power in the system.



Solar Cell

◆ Solar Cell (690.2)

- The basic photovoltaic device that generates dc electricity when exposed to light. A typical silicon solar cell produces about 0.5 volt and up to 6 amps and 3 watts for larger area cells.





Photovoltaic Modules

◆ Module (690.2)

- A complete, environmentally protected unit consisting of solar cells, optics, and other components, exclusive of tracker, designed to generate dc power when expose to sunlight.

60 watt polycrystalline
module



75 watt crystalline
module



Photovoltaic Panels

◆ Panel (690.2)

- A collection of modules mechanically fastened together, wired, and designed to provide a field installable unit.





Photovoltaic Arrays

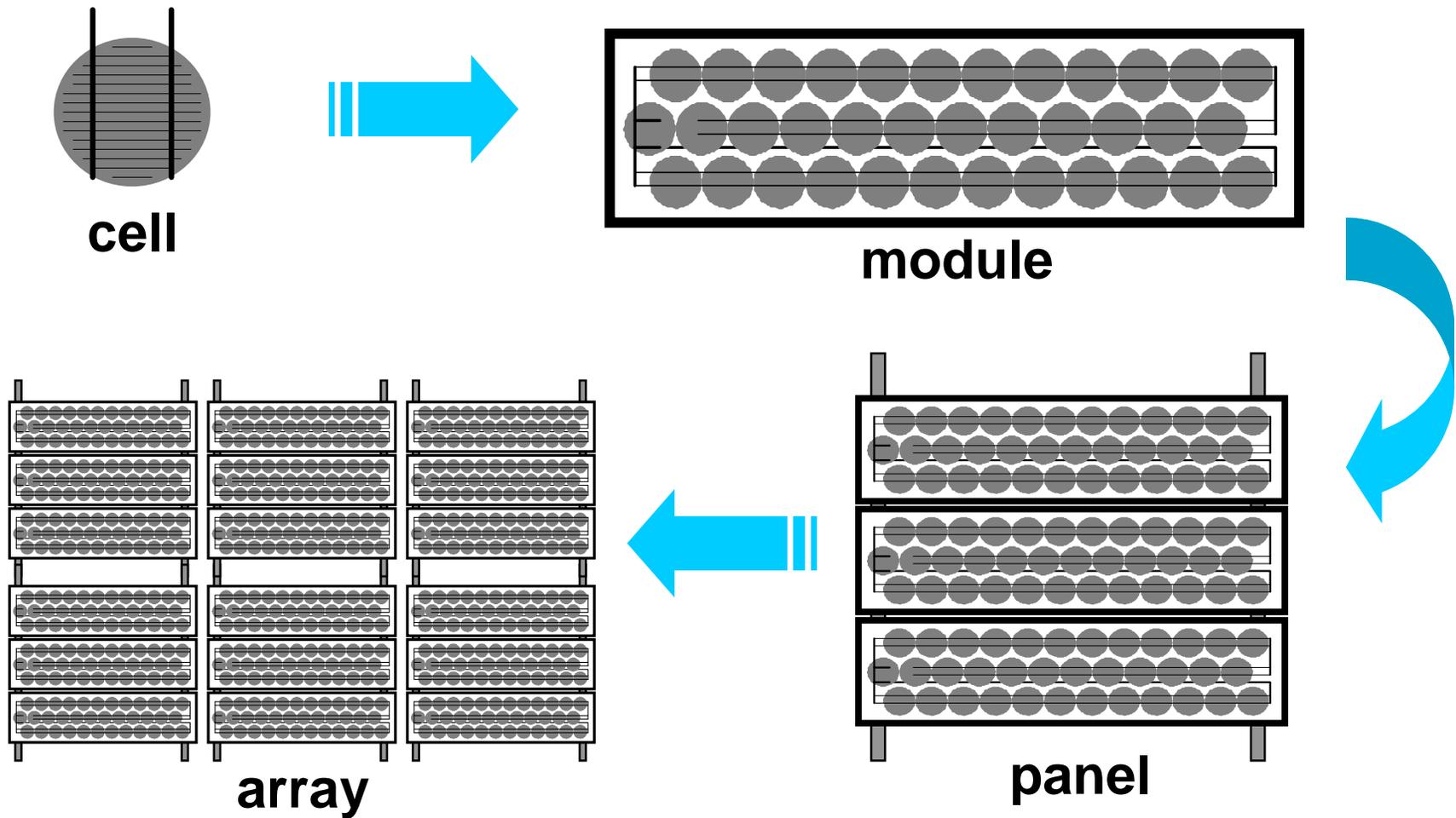
◆ Array (690.2)

- A mechanical integrated assembly of modules or panels with a support structure and foundation, tracker, and other components, as required, to form a direct-current power-producing unit.



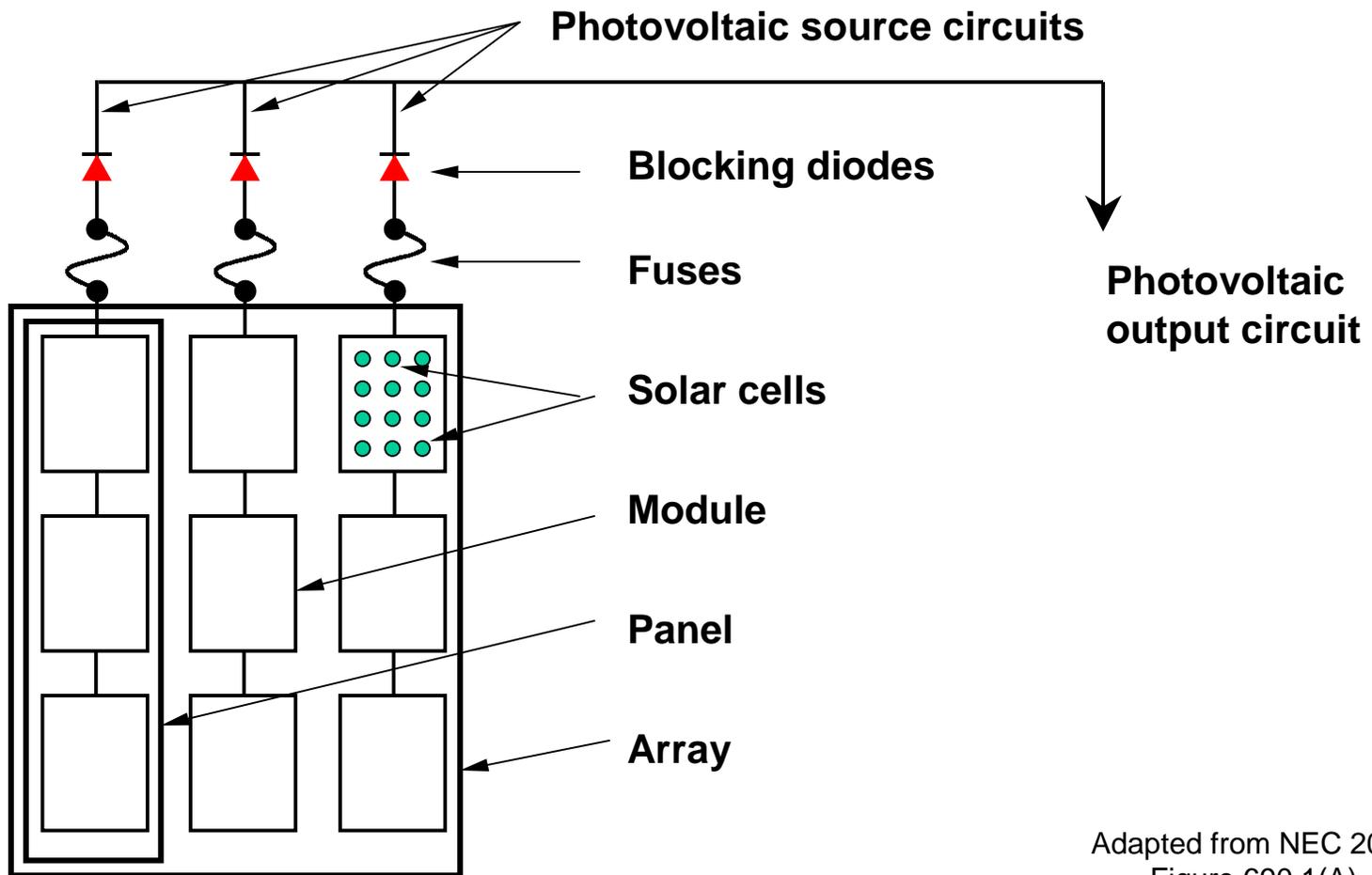


Definitions: Photovoltaic Cells, Modules, Panels and Arrays





Identification of Solar Photovoltaic System Components



Adapted from NEC 2002
Figure 690.1(A)



Inverter

◆ **Inverter (690.2)**

- Equipment that is used to change voltage level or waveform, or both, of electrical energy. Also known as a power processing unit (PCU) or power conversion system (PCS), and inverter is a device that changes dc input to ac output. Inverters may also function as battery chargers that use alternating current from another source and convert it into direct current for charging batteries.



Bi-Polar Array

◆ **Bipolar Photovoltaic Array (690.2)**

- A photovoltaic array that has two outputs, each having opposite polarity to a common reference point or center tap.



Definitions (Art. 690.2)

◆ **Blocking Diode**

- A diode used to block reverse flow of current into a photovoltaic source circuit. Blocking diodes are not required by this Code, although the instructions or labels supplied with the photovoltaic module may require them.

◆ **Charge Controller**

- Equipment that controls dc voltage or dc current, or both, used to charge a battery.

◆ **Diversion Charge Controller**

- Equipment that regulates the charging process of a battery by diverting power from energy storage to direct-current or alternating current loads or to an interconnected utility service.



Definitions (Art. 690.2)

◆ **Electrical Production and Distribution Network**

- A power production, distribution and utilization system, such as a utility system and connected loads, that is external to and not controlled by the photovoltaic power system.

◆ **Hybrid System**

- A system comprised of multiple power sources. These power sources may include photovoltaic, wind, micro-hydro generators, engine-driven generators, and others, but do not include electrical production and distribution network systems. Energy storage systems, such as batteries, do not constitute a power source for the purpose of this definition.



Definitions (Art. 690.2)

◆ **Inverter Input Circuit**

- Conductors between the inverter and batteries in stand-alone systems or the conductors between the inverter and photovoltaic output circuits for electrical production and distribution network.

◆ **Inverter Output Circuit**

- Conductors between the inverter and an ac load center for stand-alone systems or the conductors between the inverter and the service equipment or another electric power production source, such as a utility, for electrical production and distribution network.



Definitions (Art. 690.2)

◆ **Photovoltaic Power Source**

- An array or aggregate of arrays that generates dc power at system voltage and current.

◆ **Photovoltaic Source Circuit**

- Circuits between modules and from modules to the common connection point(s) of the dc system.

◆ **Photovoltaic Systems Voltage**

- The direct current (dc) voltage of any photovoltaic source or photovoltaic output circuit. For bipolar or multiwire installations, the photovoltaic systems voltage is the highest voltage between any two dc conductors.

◆ **Photovoltaic Output Circuit**

- Circuit conductors between the photovoltaic source circuit(s) and the inverter or dc utilization equipment.



Types of Photovoltaic Systems

◆ Stand-Alone Systems

- Operate independent of the utility grid, includes hybrid systems

◆ Utility-Interactive Systems

- Sometimes called grid-connected systems
- Operate interconnected (in parallel) with the utility grid, a bi-directional interface is required

◆ Bi-Modal Systems

- May operate in either utility-interactive or stand-alone mode, but not concurrently



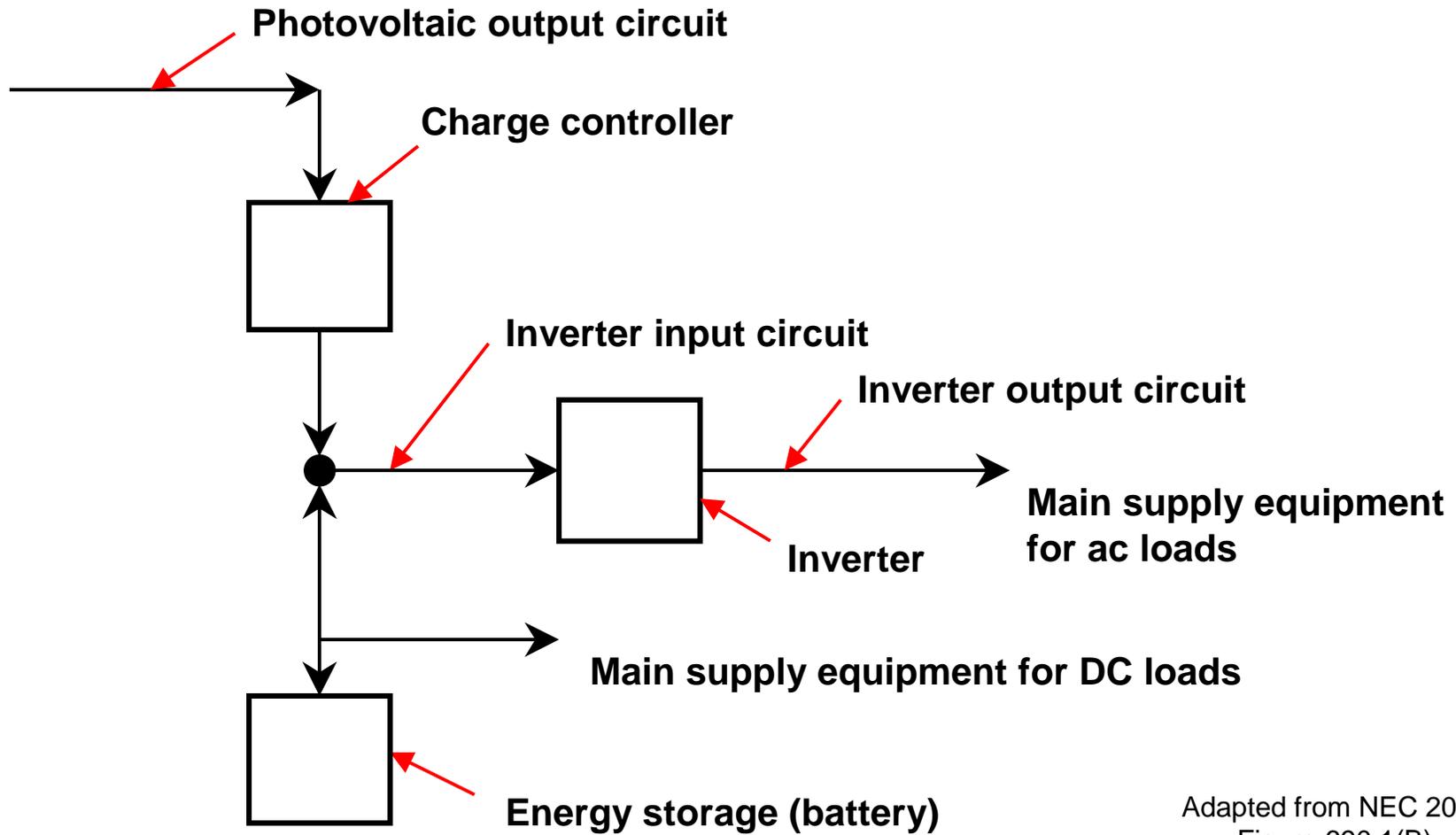
Stand-Alone Systems

◆ **Stand-Alone System (690.2)**

- A solar photovoltaic system that supplies power independently of an electrical production and distribution network.
- ◆ Operate autonomously, or independent of the electric utility grid.
- ◆ Commonly used for back-up power and where the costs of extending utility service and other power generating means are cost-prohibitive.
- ◆ May or may not use energy storage.
- ◆ Used to power DC loads and/or AC loads from an inverter.
- ◆ Hybrid stand-alone systems may include other energy producing equipment such as engine generators, wind turbines, fuel cells or small hydro.



Stand-Alone System

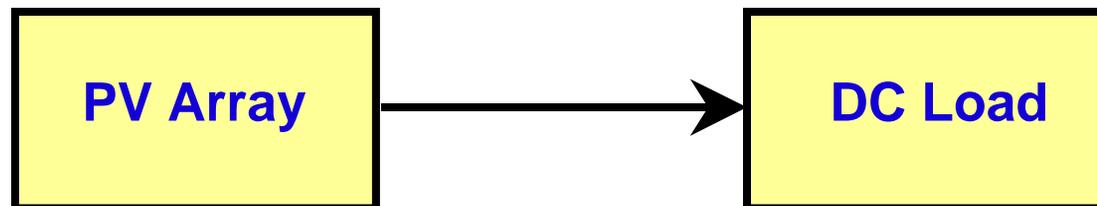


Adapted from NEC 2002
Figure 690.1(B)



Direct-Coupled Stand-Alone Systems

- ◆ Simplest type of stand-alone PV system, common applications include water pumps and fans.
- ◆ DC load is directly connected to a PV array, no energy storage.
- ◆ No overcurrent device typically required.





Stand-Alone PV System with Battery Storage

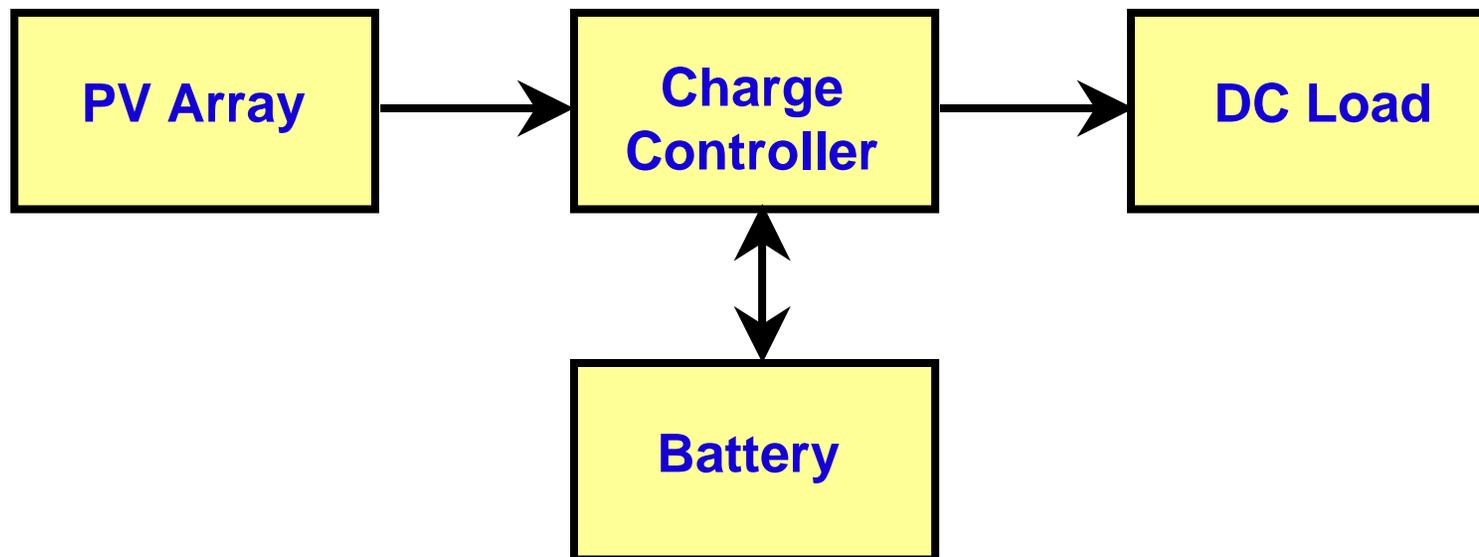
- ◆ PV array charges battery which supplies power to DC electrical loads as needed.
- ◆ Without charge control, battery is susceptible to overcharge and overdischarge.
- ◆ Charge control may only be eliminated under special circumstances the load is well defined and the battery is oversized.





Stand-Alone PV System with Batteries and Charge Control

- ◆ Charge control is required whenever the load is variable and the battery is not oversized.
- ◆ Protects the battery from overcharge and overdischarge, and may provide load control functions.



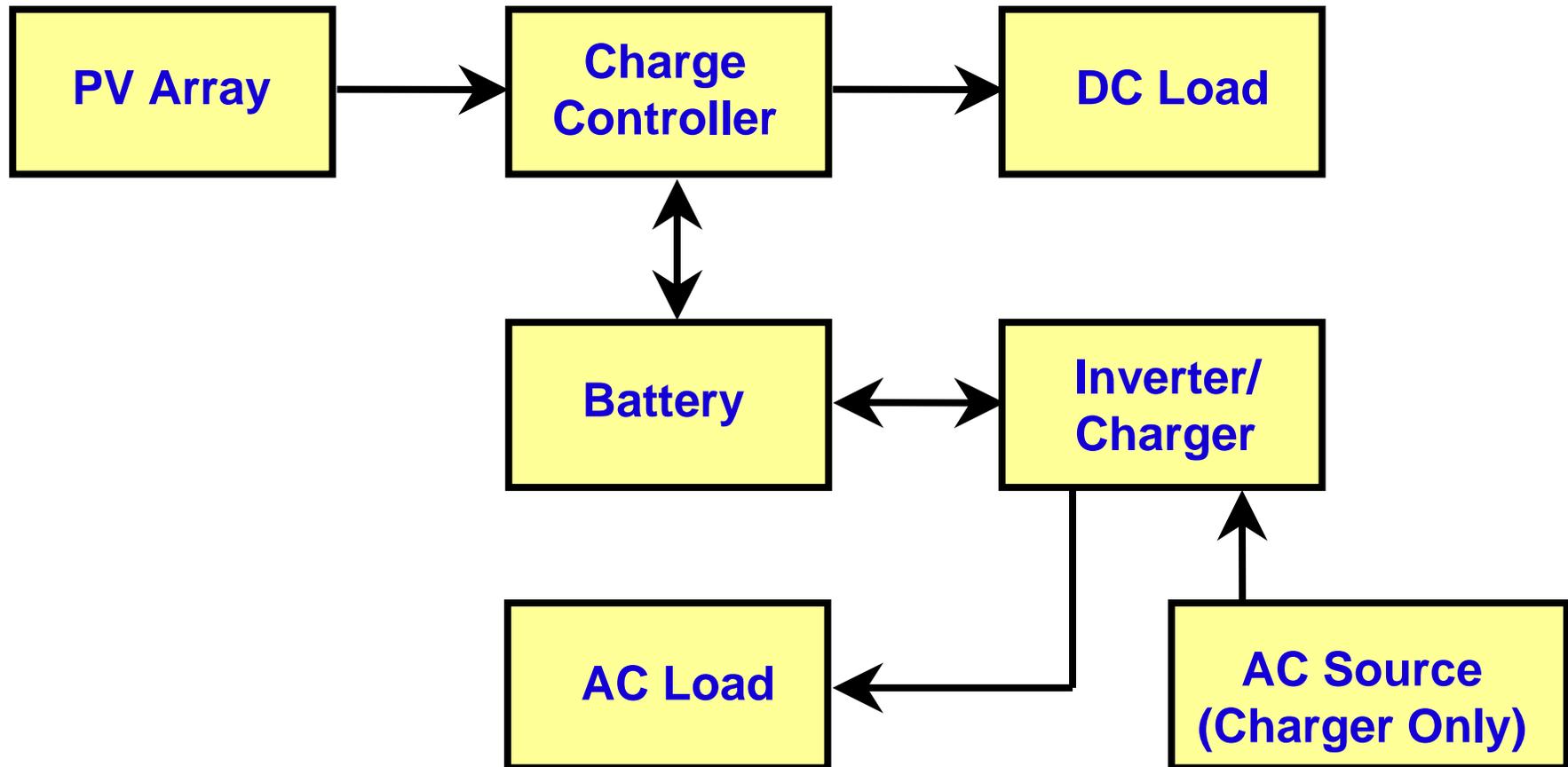


Stand-Alone PV System with AC and DC Loads

- ◆ The addition of inverter is required to power AC loads from the battery bank.
- ◆ Inverter may incorporate a charger function, which allows inverter to be connected to a generator or utility grid to charge batteries or supplement the AC load.
 - Note that there is no back-feed of power to the utility grid and this is not a utility-interactive system – the grid is used strictly for back-up.
 - The inverter charger AC input is separate from the AC output of the inverter – the AC output of stand-alone inverters operating from batteries is never connected to the grid – only the dedicated AC loads served by the system.



Stand-Alone PV System with AC and DC Loads





Stand-Alone PV Hybrid Systems

- ◆ One or more energy sources are used in addition to the PV generator.
- ◆ Common hybrid sources used in stand-alone PV systems include engine generators, wind turbines, small hydro and fuel cells.
- ◆ Reliance on any single generating source is reduced, battery storage capacity and size of PV array can be minimized.
- ◆ Hybrid PV systems are often the least costly for remote power applications.



Stand-Alone PV Hybrid System

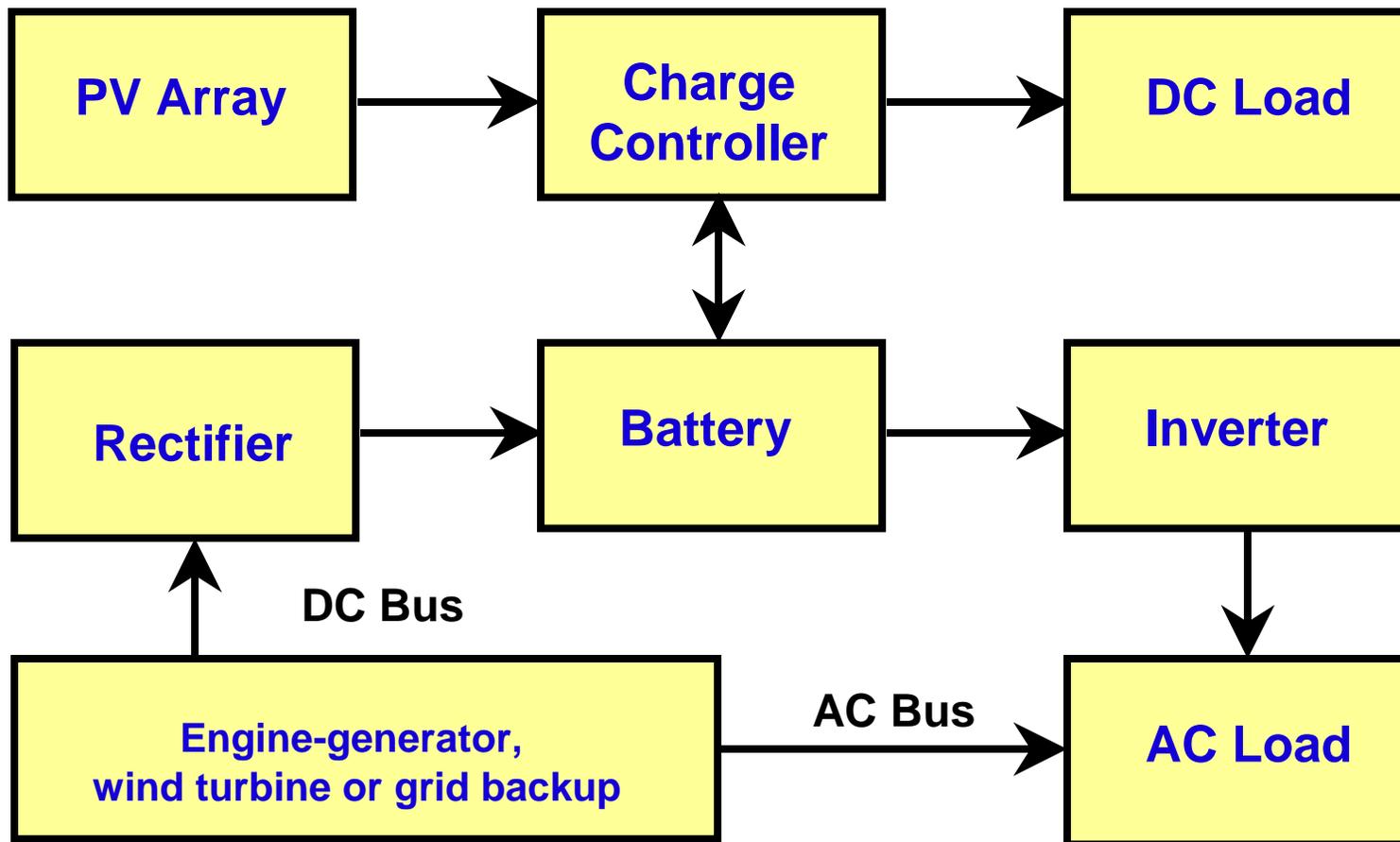
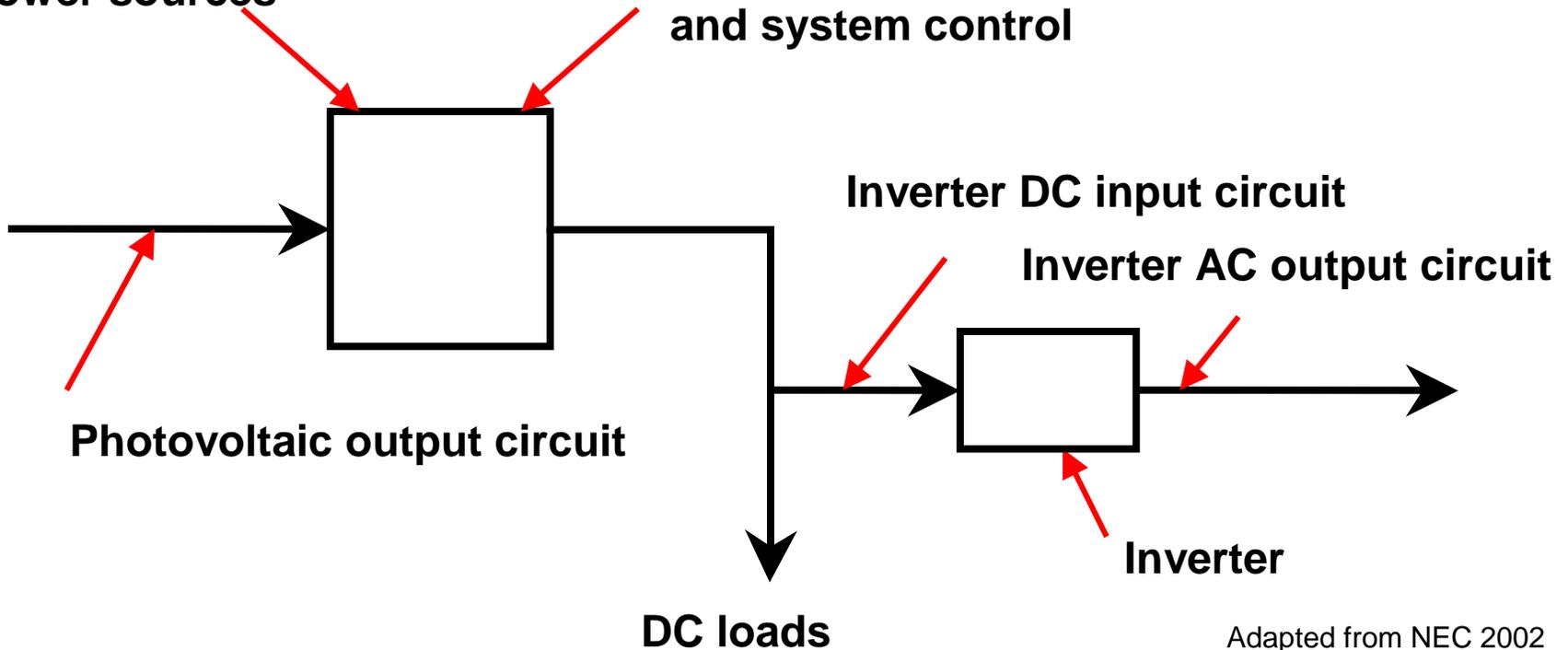




Figure 690.1(B) Hybrid System

Wind, engine-generator,
micro-hydro and other
power sources

Energy storage, charge controller
and system control



Adapted from NEC 2002
Figure 690.1(B)



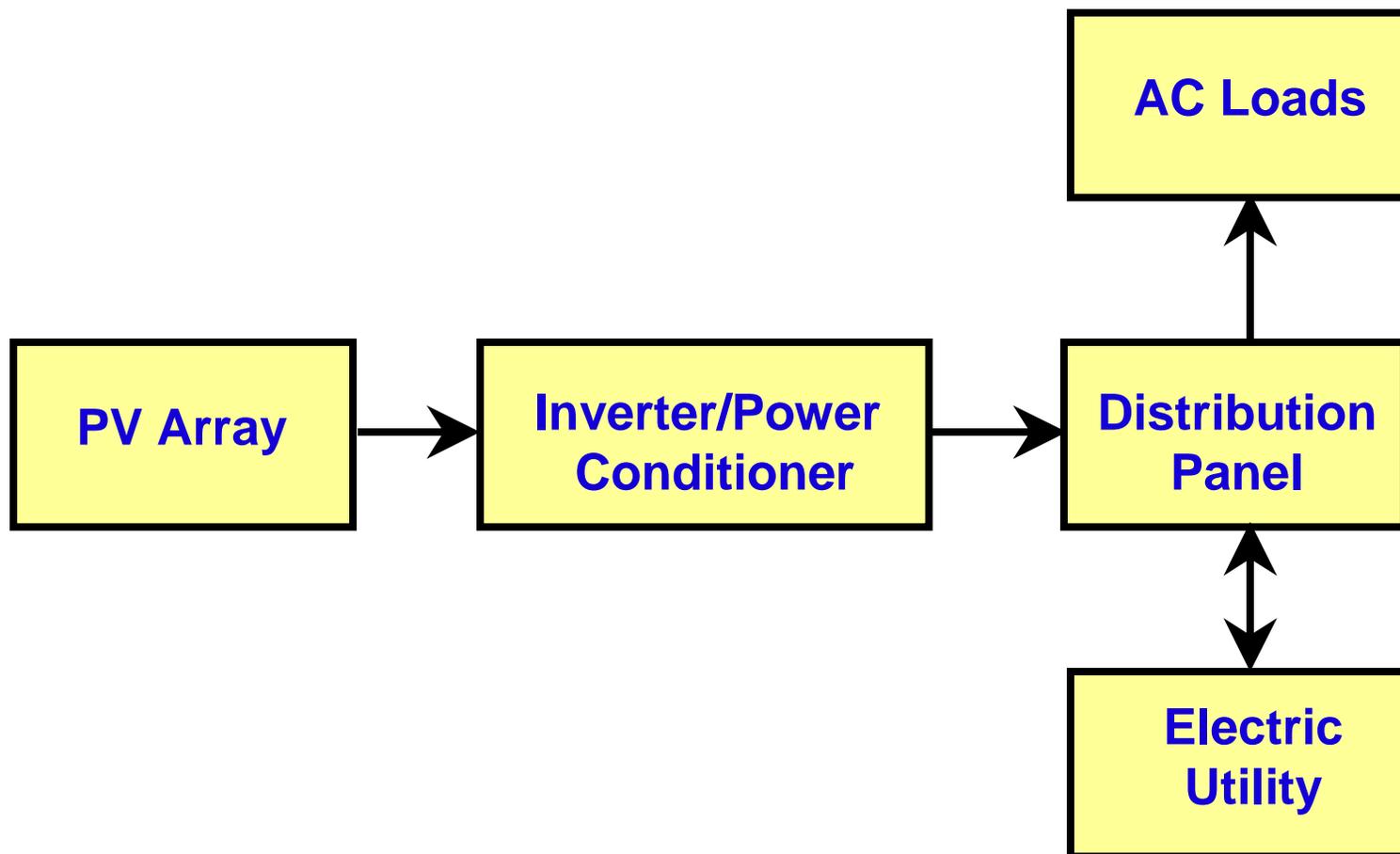
Interactive System

◆ **Interactive System (690.2)**

- A solar photovoltaic system that operates in parallel with and may deliver power to an electrical production and distribution network. For the purposes of this definition, and energy storage subsystem of a solar photovoltaic system, such as a battery, is not another electrical production source.

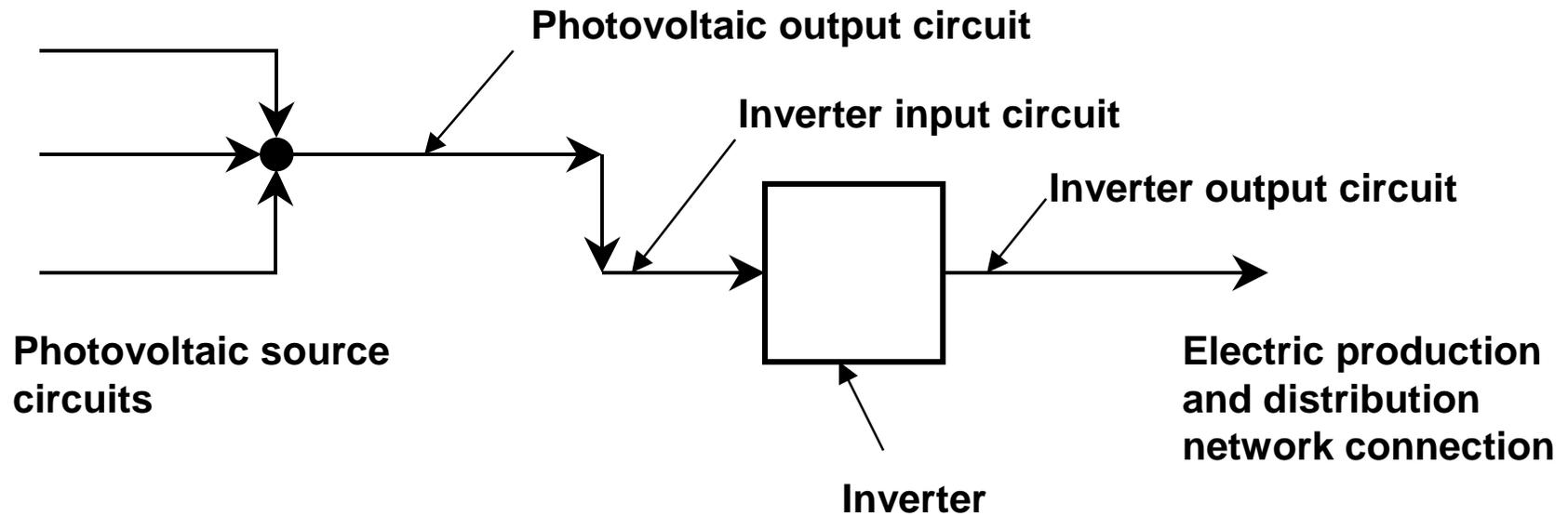


Basic Utility-Interactive or Grid-Connected PV System





Interactive System



Adapted from NEC 2002
Figure 690.1(B)



Utility-Interactive Systems

- ◆ Operate in parallel with the utility grid, a bi-directional interface is required
- ◆ The inverter, or power conditioning equipment is the primary component.
- ◆ Electrical loads are supplied by either the PV system or utility.
- ◆ Generally do not use energy storage, but bi-modal systems may use batteries for critical load backup.
- ◆ Electrical utilities may require accessible, visible disconnects and special metering.



Utility-Interactive System - Bi-Modal Configuration

