RENEWABLE ENERGY SYSTEMS

HYBRID ENERGY SYSTEMS

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Outline

- Hybrid Energy Systems (HES)
  - The need for HES
  - Elements of HES
  - HES Configurations
  - AC coupling vs. DC coupling ?
  - Stand-alone vs. Grid-connected Systems
  - Modeling of HES
  - Practical HES Examples

Water Heating Case Study

- Compare the total cost (Capital and running) for the following types of water heating:
  - Solar type
  - Electric type
  - Gas type
- Assuming the following data:
  - Daily hot water usage = 150 liters, 6 hours/day
  - Hot water temperature = 65 Co
  - Cold water temperature = 20 Co
  - The capital cost of solar heater = L.E. 4000,
  - Bank interest rate = 10%

- Annual maintenance for solar system= L.E. 75 and 20 years life time.
- Assuming 30 days/year without solar thermal, and using electric system
- The capital cost of electric heater = L.E. 1500
- Annual maintenance for electric system= L.E. 50
- The Electricity cost (flat rate) = 0.5 - 1.5 L.E. /kWh
- The capital cost of gas heater = L.E. 2000
- The cost of gas bottle, 14 m^3 = L.E. 10 - 15, and consumed in one week
- Annual maintenance for gas system= L.E. 60

The Needs for HES

- Limitations of single source energy systems;
  - Reliability
  - Cost
  - Inconsistent nature of renewable energy resources.

- Different renewable energy sources can complement each other, multi-source hybrid alternative energy systems (with proper control) have great potential to provide higher quality and more reliable power to customers than a system based on a single resource.

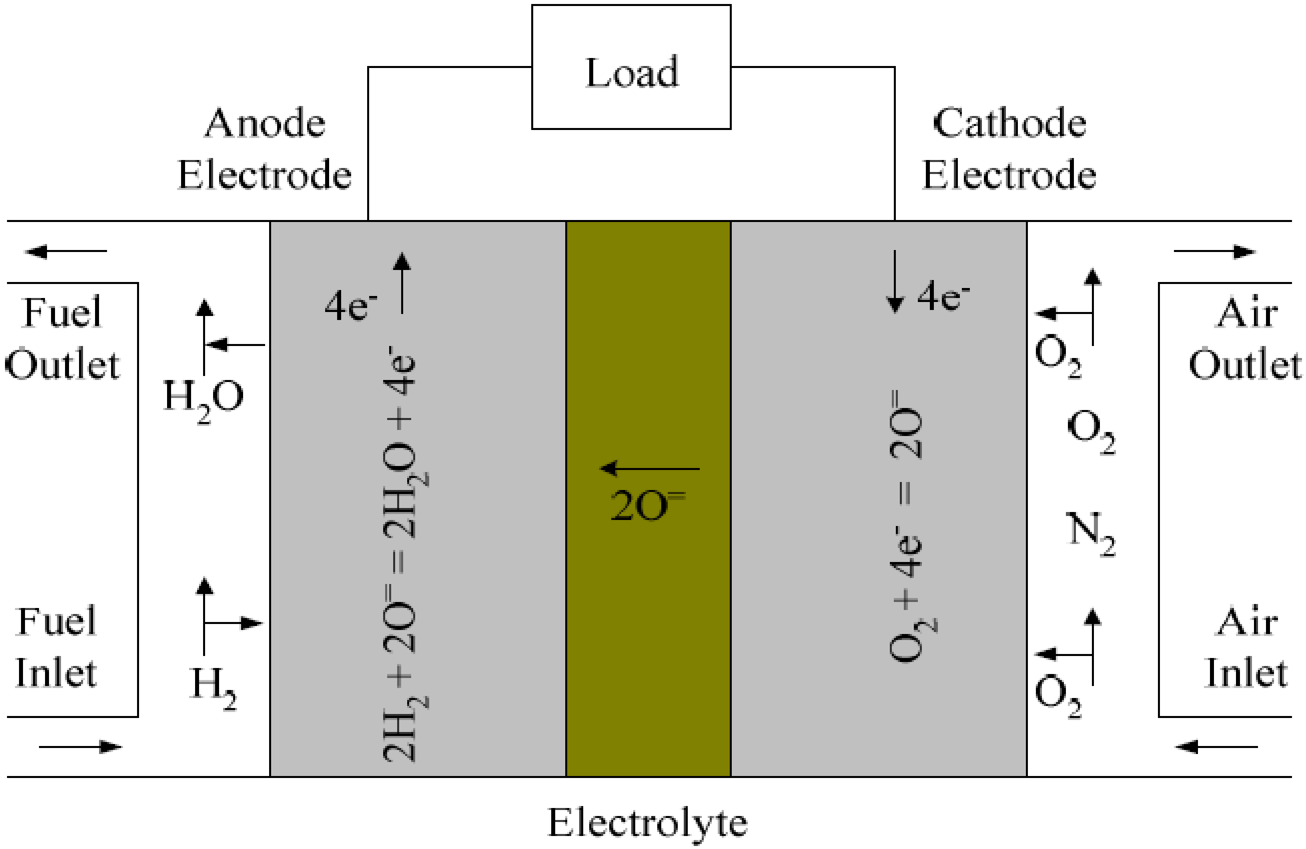
Elements of HES

- Two or more energy resources (with at least one renewable energy source).
- Energy storage element.
- Energy storage controller.
- Power electronics interfacing.
- Power electronics interfacing controller.
- Overall system controller.
- Fuel Cell and/or Electrolyzer.

Fuel Cell - Introduction

- Fuel cells (FCs) are static energy conversion devices that convert the chemical energy of fuel directly into DC electrical energy.
- The basic physical structure of a fuel cell consists of two electrodes (anode and cathode) and an electrolyte layer in the middle.
- The electrolyte layer is a good conductor for ions (positive or negative charged), but NOT for electrons.
- The electrolyte can either be solid, such as polymer electrolyte membrane fuel cell (PEMFC) and solid oxide fuel cells (SOFC) or liquid, such as molten carbonate fuel cells (MCFC).

Schematic diagram of a SOFC



Fuel Cell History

1801
Humphry Davy demonstrates the principle of what became fuel cells.

1839
William Grove invents the 'gas battery', the first fuel cell.

1889
Charles Langer and Ludwig Mond develop Grove's invention and name the fuel cell.

1950s
General Electric invents the proton exchange membrane fuel cell.

1959
Francis Bacon demonstrates a 5 kW alkaline fuel cell.

1960s
NASA first uses fuel cells in space missions.

1970s
The oil crisis prompts the development of alternative energy technologies including PAFC.

1980s
US Navy uses fuel cells in submarines.

1990s
Large stationary fuel cells are developed for commercial and industrial locations.

2007
Fuel cells begin to be sold commercially as APU and for stationary backup power.

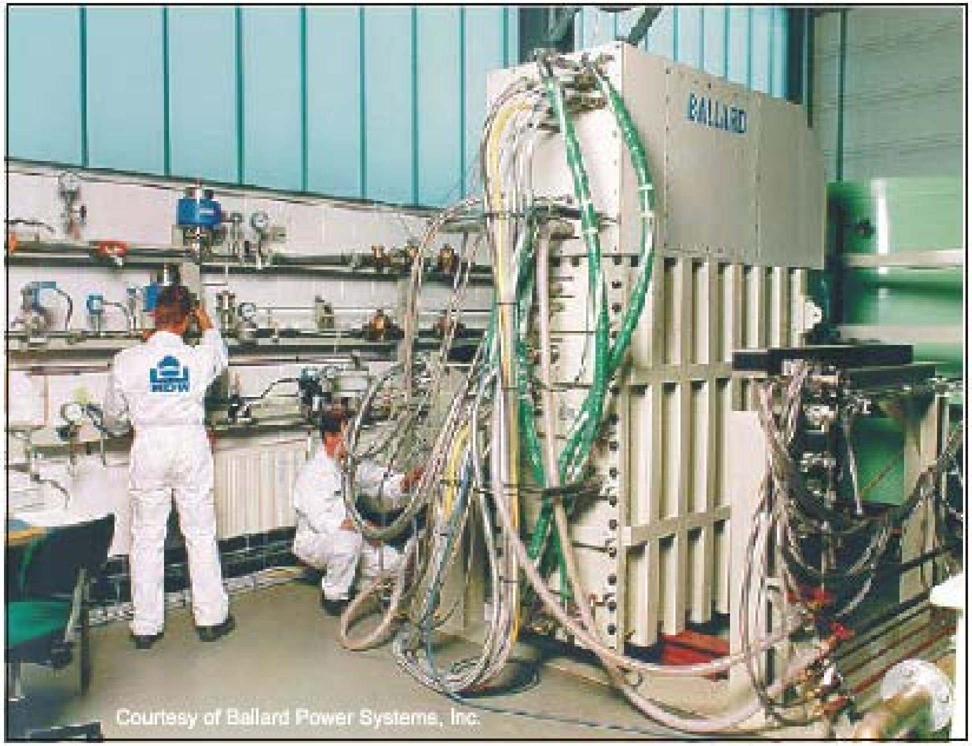
2008
Honda begins leasing the FCX Clarity fuel cell electric vehicle.

2009
Residential fuel cell micro-CHP units become commercially available in Japan. Also thousands of portable fuel cell battery chargers are sold.

Fuel Cell applications

- Stationary Systems
- Transportation Systems
- Space Systems
- Portable Systems

Stationary Systems



This 80 kW powerplant was built by Ballard Power Systems for German submarine manufacturer Howaldtswerke-Deutsche Werft AD and operates using pure hydrogen and oxygen.

Transportation Systems

Phase 1 Bus (1993)

Phase 2 Bus (1995)

Phase 3 Bus (1998). A fleet of six of these buses was put into revenue service in Vancouver and Chicago for 2 years.

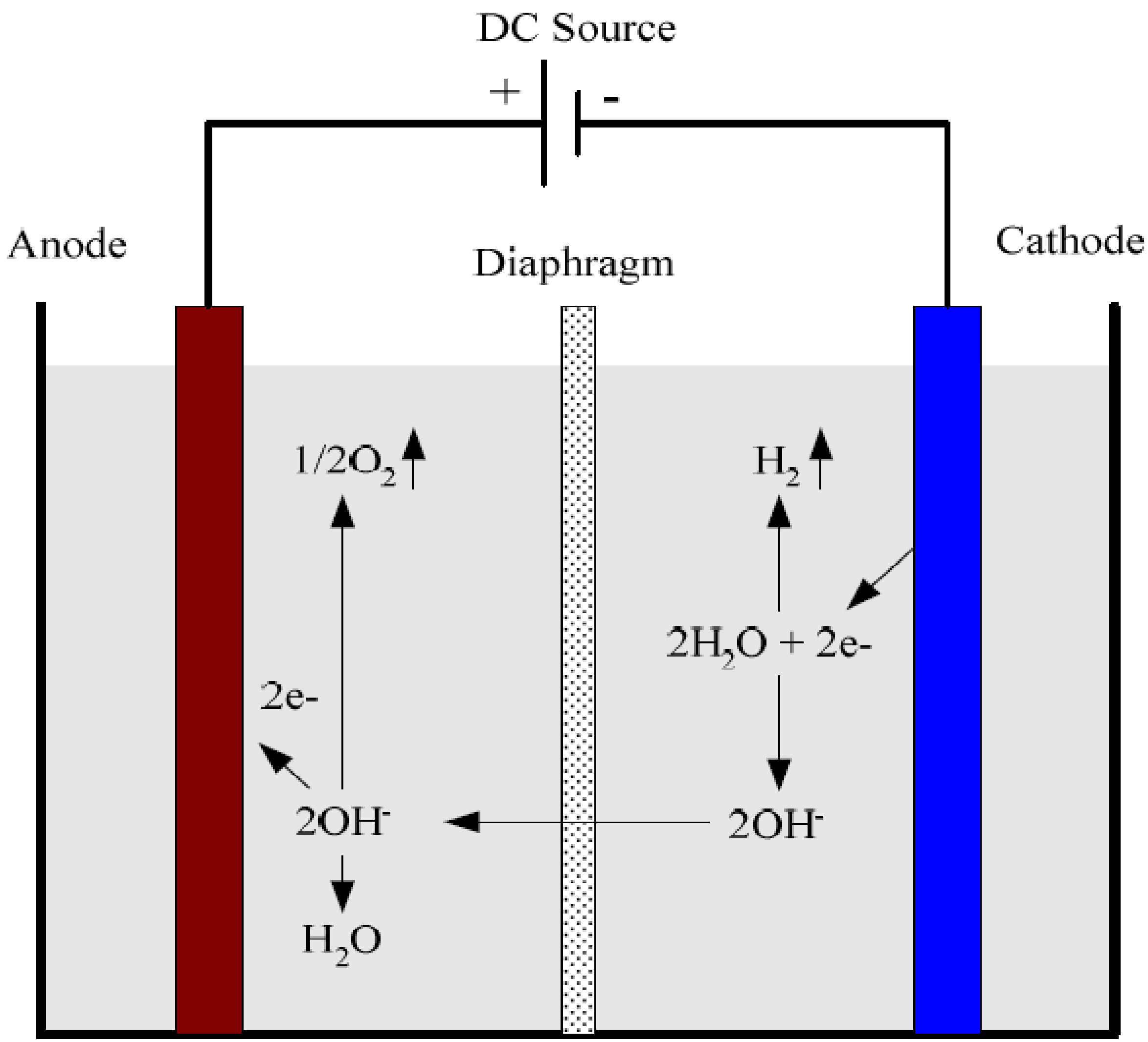
Phase 4 Bus (2000). This bus endured desert conditions during a 1 year field trial in Palm Springs.

- Buses are most commercially advanced applications of fuel cells to date.
- Currently being used by many American and European cities.

Electrolyzer

- An electrolyzer is a device that produces hydrogen and oxygen from water.
- Water electrolysis can be considered a reverse process of a hydrogen fueled fuel cell.
- Opposite to the electrochemical reaction occurring in fuel cell, an electrolyzer converts the DC electrical energy into chemical energy stored in hydrogen.

Schematic diagram of an alkaline electrolyzer



HES Configurations

1)Wind/PV/FC/electrolyzer/battery system.

2) Micro-turbine/FC system.

3) Microturbine/wind system.

4) Gas-turbine/FC system.

5) Diesel/FC system.

6) PV/battery.

7) PV/FC/electrolyzer.

HES Configurations (2)

8) PV/FC/electrolyzer/battery system.

9) FC/battery, or super-capacitor system.

10) Wind/FC system .

11) Wind/diesel system.

12) Wind/PV/battery system.

13) PV/diesel system.

14) Diesel/wind/PV system.

15) PV/FC/ Super-conducting Magnetic Energy Storage (SMES) system.

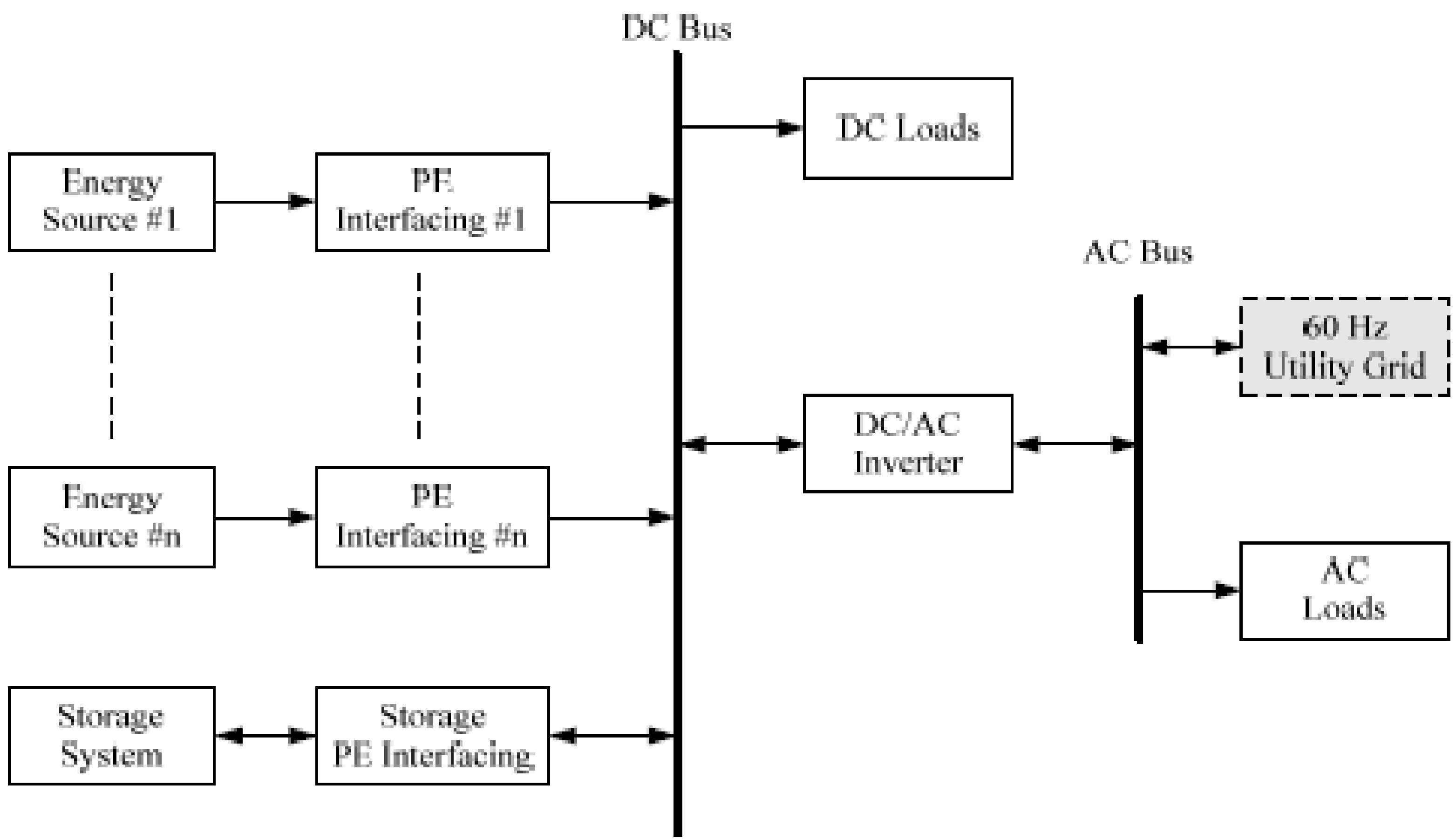
AC coupling vs. DC coupling ?

- There are several ways to integrate different alternative energy sources to form a hybrid system.

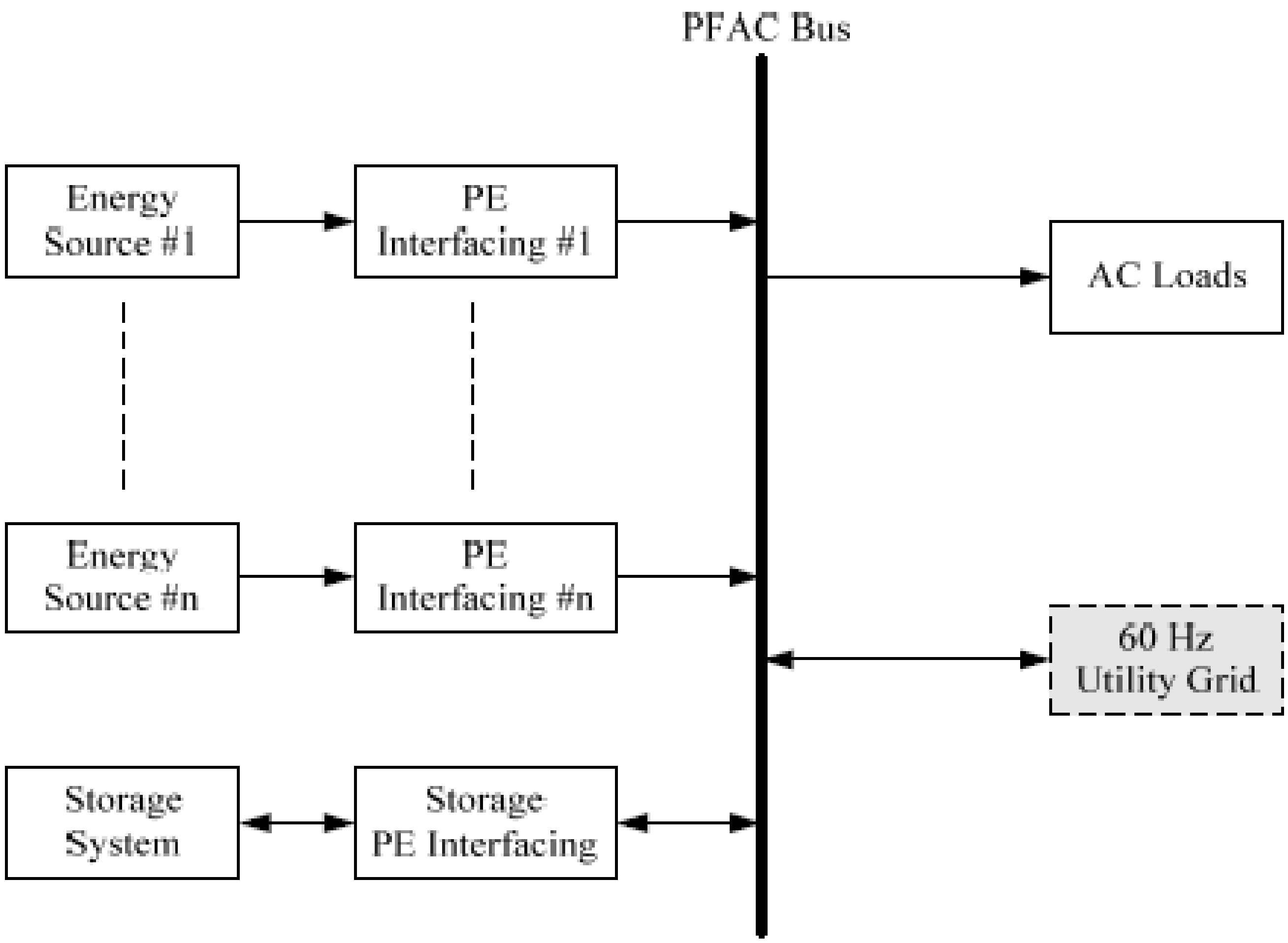
- The methods can be generally classified into two categories: DC coupling and AC coupling.

- AC coupling can be classified further into power frequency AC (PFAC) coupling and high frequency AC (HFAC) coupling.

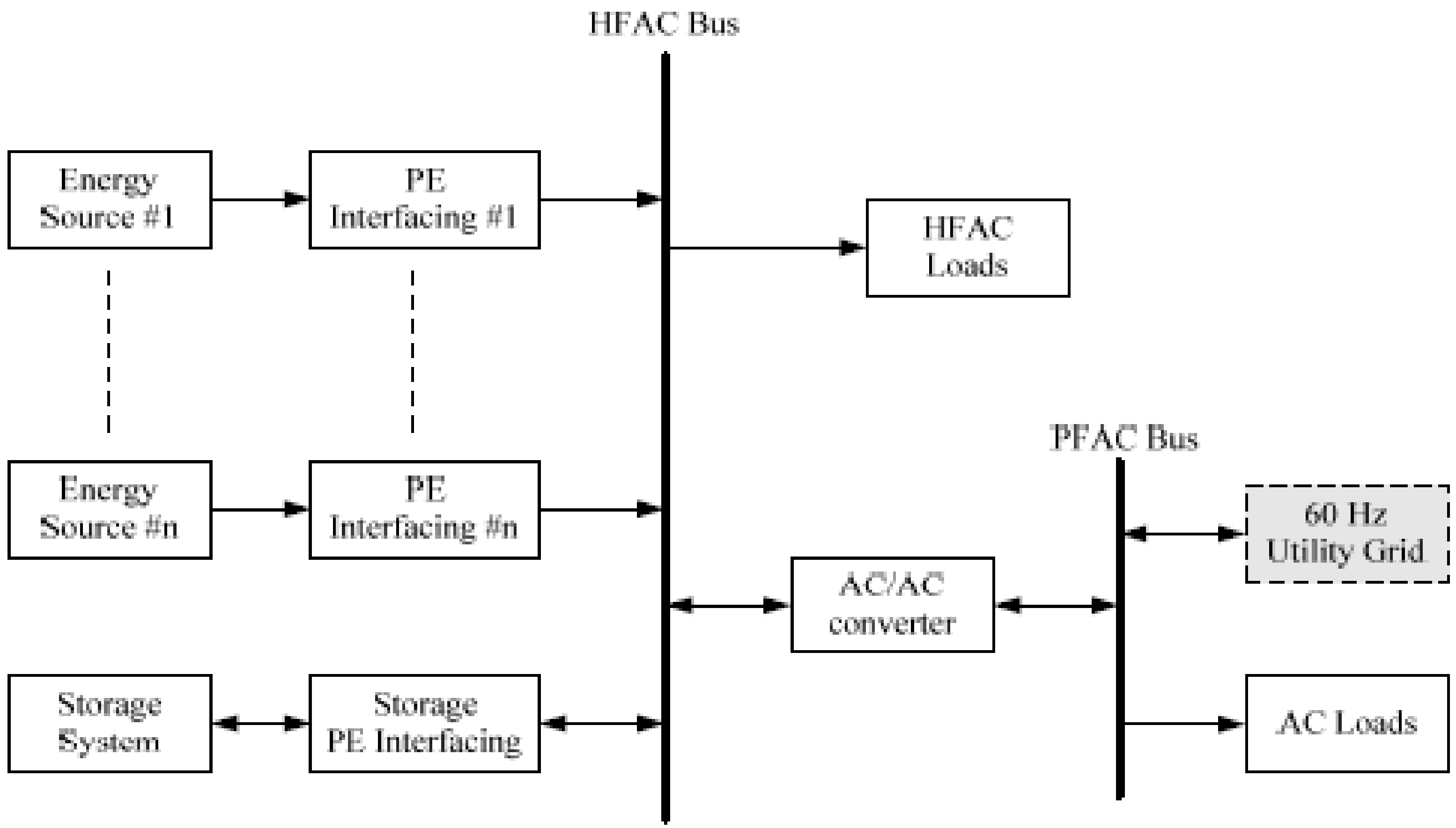
Hybrid energy system integration: DC coupling



Hybrid energy system integration: PFAC coupling



Hybrid energy system integration: HFAC coupling



Coupling Scheme	Advantage	Disadvantage
DC	1. Synchronism not needed. 2. Suitable for long distance transmission; it has less transmission losses. 3. Single-wired connection	1. Concerns on the voltage compatibility 2. Corrosion concerns with the DC electrodes. 3. Non-standard connection requires high costs in installing and maintenance. 4. If the DC/AC inverter is out of service, the whole system fails to supply AC power.
PFAC	1. High reliability. If one of the energy sources is out of service, it can be isolated from the system easily. 2. Ready for grid connection. 3. Standard interfacing and modular structure. 3. Easy multi-voltage and multi-terminal matching. 4. Well established scale economy.	1. Synchronism required. 2. The need for power factor and harmonic distortion correction. 3. Not suitable for long distance transmission.
HFAC	1. Higher order harmonics can be easily filtered out. 2. Suitable for applications with HFAC loads with improved efficiency. 3. Size of high frequency transformers, harmonic filters and other passive components are smaller.	1. Complex control 2. Higher component and maintenance costs due to high frequency. 3. The dependence on future advances of power electronics. 4. Concerns about electromagnetic compatibility. 5. Extremely limited capability of long distance transmission.

Stand-alone vs. Grid-connected Systems

- A hybrid alternative energy system can either be stand-alone or grid-connected if utility grid is available.

- For a stand-alone application, the system needs to have sufficient storage capacity to handle the power variations from the alternative energy sources involved. A system of this type can be considered as a micro-grid, which has its own generation sources and loads.

- For a grid-connected application, the alternative energy sources in the micro-grid can supply power both to the local loads and the utility grid.

Stand-alone vs. Grid-connected Systems (2)

- In addition to real power, these DG sources can also be used to give reactive power and voltage support to the utility grid.

- The capacity of the storage device for these systems can be smaller if they are grid-connected since the grid can be used as system backup.

- However, when connected to a utility grid, important operation and performance requirements, such as voltage, frequency and harmonic regulations, are imposed on the system.

Modeling of HES

- Due to the growing interest in the HES and hybrid systems particularly in their utilization in off-grid, standalone systems many software tools were developed to help simulation, evaluation and assessment of HES based models, not only technically but also economically. Some of these tools are listed below ;
- HOMER (Hybrid Optimization Model for Electric Renewables) is a fast and comprehensive off-grid and distributed micro-power system screening and configuration optimization model. It is widely used and provides a user friendly interface. This model is the state-of-the-art for initial system conceptual analysis.

Modeling of HES (2)

- INSEL offers almost unlimited flexibility in specifying system configurations by allowing the user to specify the connectivity on a component level. It is intended as an out-of-house-model.
- HYBRID2 is the state-of-the-art time series model for prediction of technical/economical performance of hybrid wind–photovoltaic systems. It offers very high flexibility in specifying the connectivity of systems and is quite widely used.
- WINSYS is a spreadsheet-based model implementing probabilistic representations of resources and demands. WINSYS incorporates the anticipated technical expansions during the project's lifetime in the technical performance measures combined with a traditional economic lifecycle cost assessment.

Modeling of HES (3)

- WDLTOOLS was developed by Engineering Design Tools for Wind Diesel Systems and is a package containing seven European logistic models: SOMES (The Netherlands), VINDEC (Norway), WDILOG (Denmark), RALMOD (UK) and TKKMOD (Finland). It also includes the modular electromechanical model JODYMOD, although somewhat outdated.
- RPM-Sim is a model that uses the VisSim visual environment and allows for the dynamic analysis of wind, PV and diesel systems. Researchers at the U.S. National Renewable Energy Laboratory (NREL) / National Wind Technology Center developed the model.


Thanks

Any Questions...
Just Ask!