National Wind Technology Center

Energy Storage for Hybrid Village Power Systems

Village Power '98
Technical Workshop

Steve Drouilhet

Sr. Engineer

National Renewable Energy Laboratory

Golden, Colorado, USA

Defining the Energy Storage Capacity

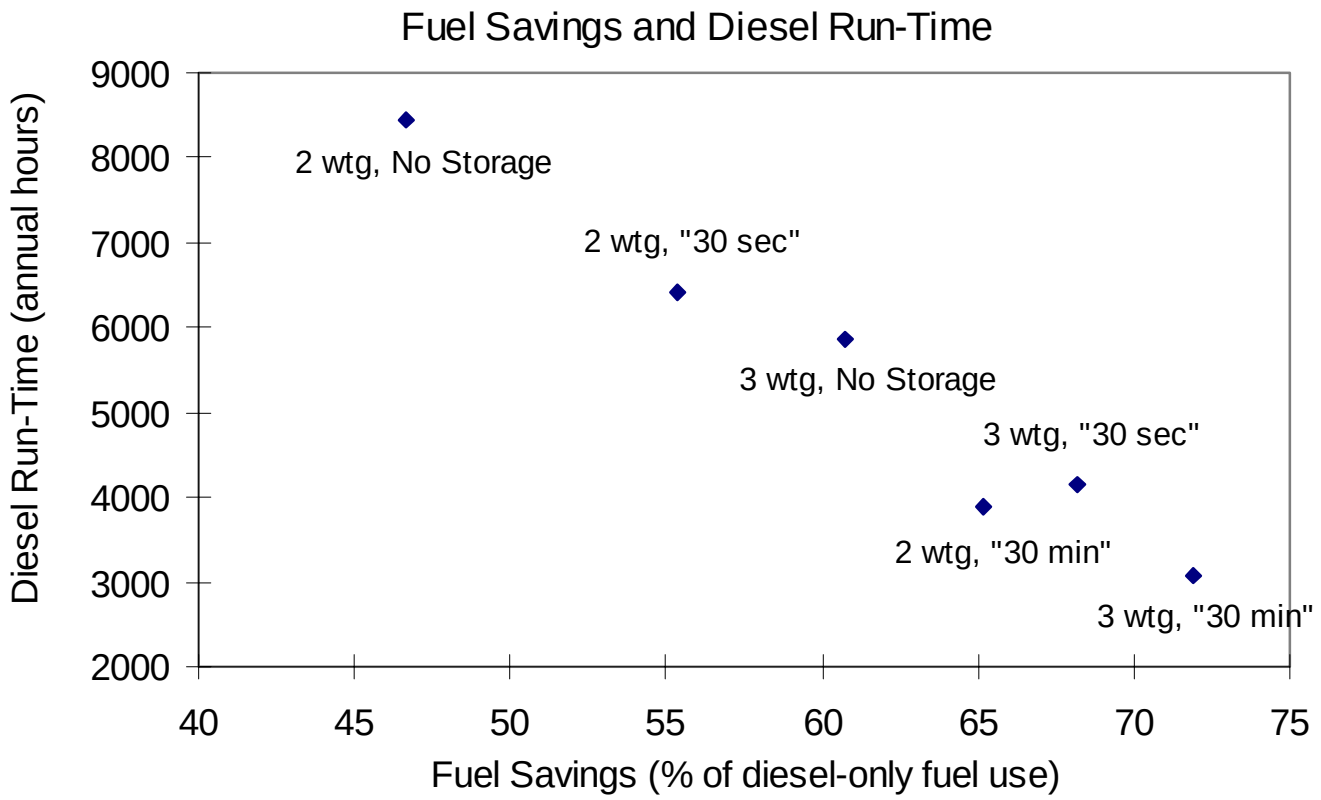
- It is convenient to define storage capacity in terms of the time that the nominal energy capacity could cover the load at rated power.
- Example: What is the nominal power duration of a 250VDC, 200 amp-hr battery in a power system rated at 100 kW?

$$Capacity = \frac{(200 \cdot \text{Amp} \cdot \text{hr})(250 \cdot \text{Volts})}{100 \cdot \text{kW}} = 30 \cdot \text{minutes}$$

Hybrid Power Systems Use Various Amounts of Energy Storage Depending on the Objective

Storage Capacity	Function of Energy Storage
Very short term (less than 1 minute)	Helps cover the load during the time it takes to start and synchronize the backup generator. • increases system reliability • reduces required reserve capacity
Short term (5-60 minutes)	Helps cover the load during short term load peaks or wind energy deficits, eliminating the need to start the backup generator. • significant reduction in diesel run time and fuel consumption
Medium term (2-12 hour)	Stores excess renewable energy to be used to meet the load later in the day. • Further reduction in diesel run time and fuel consumption • Provides greater utilization of available renewable energy; less renewable energy is wasted
Long term (1-3 days)	Stores excess renewable energy to meet the load during days of higher than average load or lower than average renewable energy availability. • Possibly eliminates need for back up generator

Impact of Energy Storage on a High Penetration Wind-Diesel Village Power System



Applicability of Various Energy Storage Technologies to Different Storage Requirements

Storage Capacity	Technology	Status
Very short term (less than 1 minute)	NiCad Battery Lead-Acid Battery Flywheel	Commercial Commercial Near commercial
Short term (5-60 minutes)	NiCad Battery Lead-Acid Battery Flywheel	Commercial Commercial Experimental
Medium term (2-12 hour)	Lead-Acid Battery Hydrogen	Commercial Experimental
Long term (1-3 days)	Lead-Acid Battery Pumped Hydro Hydrogen	Commercial Experimental Experimental

Some Energy Storage Technologies Used or Proposed for Hybrid Village Power Systems

- Lead-Acid Battery
- Nickel-Cadmium Battery
- Flywheels (Electromechanical Battery)
- Hydrogen
- Pumped Hydro

Lead-Acid Battery

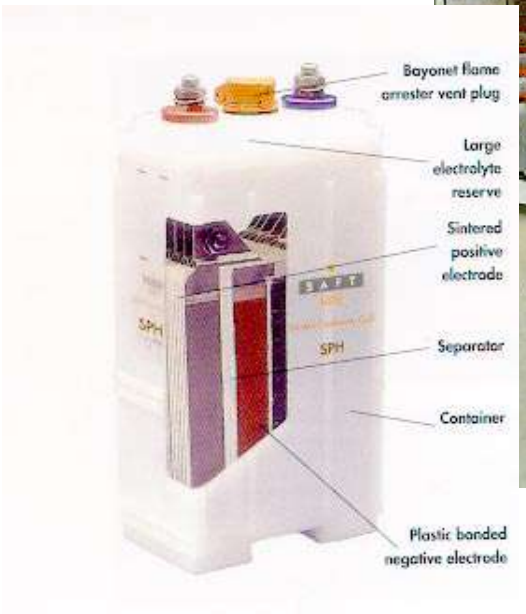
- **Well proven**
- **Reliable if handled properly**
- **Moderate cost**
- **High energy density**

- **Limited lifetime**
- **Corrosive electrolyte**
- **Not tolerant of abuse**
- **Performance suffers drastically at low temperatures.**

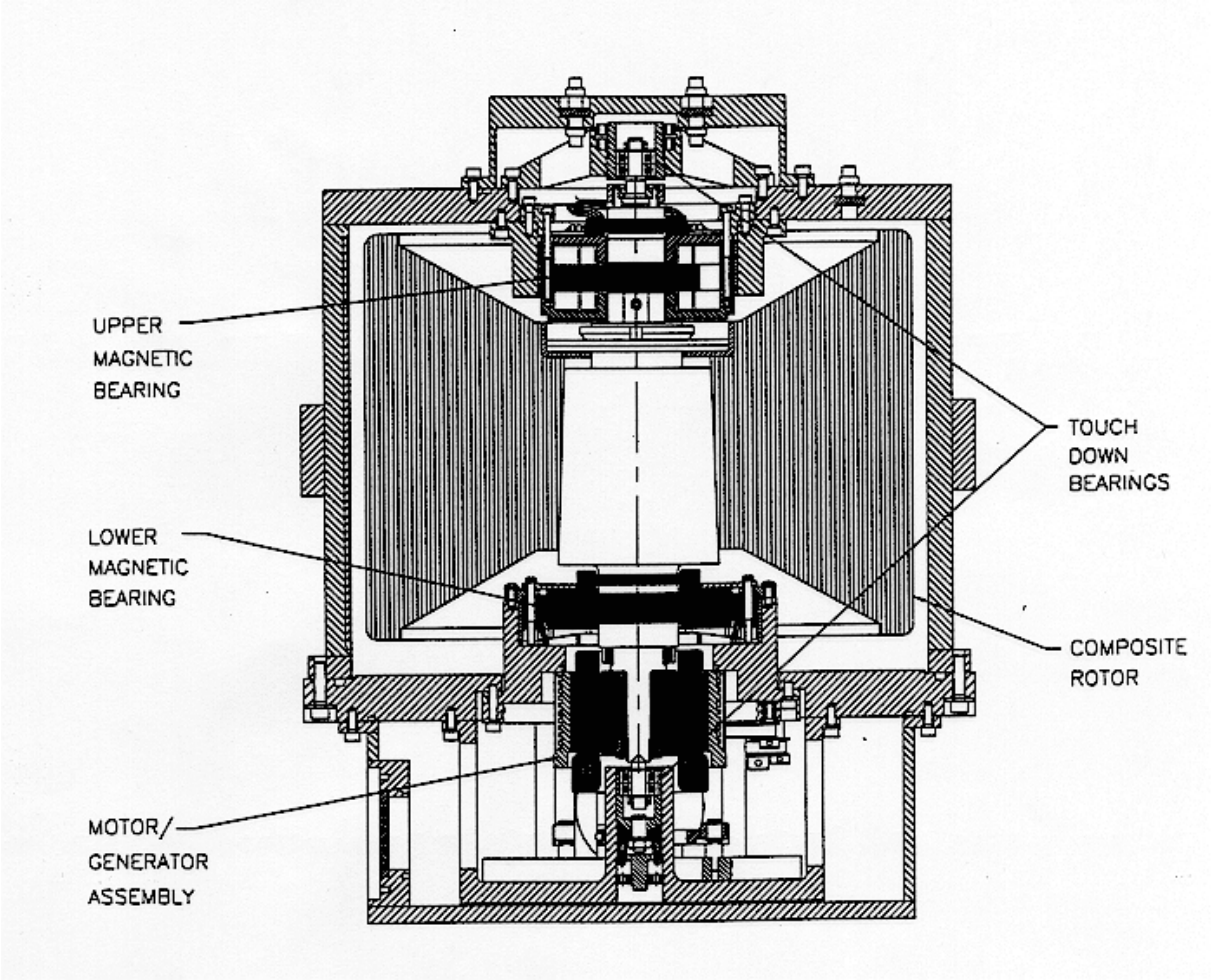
Ni-Cd Battery

- **Long life**
- **Tolerant of abuse**
- **High energy and power density**
- **Good low temperature performance**
- **Relatively light weight**

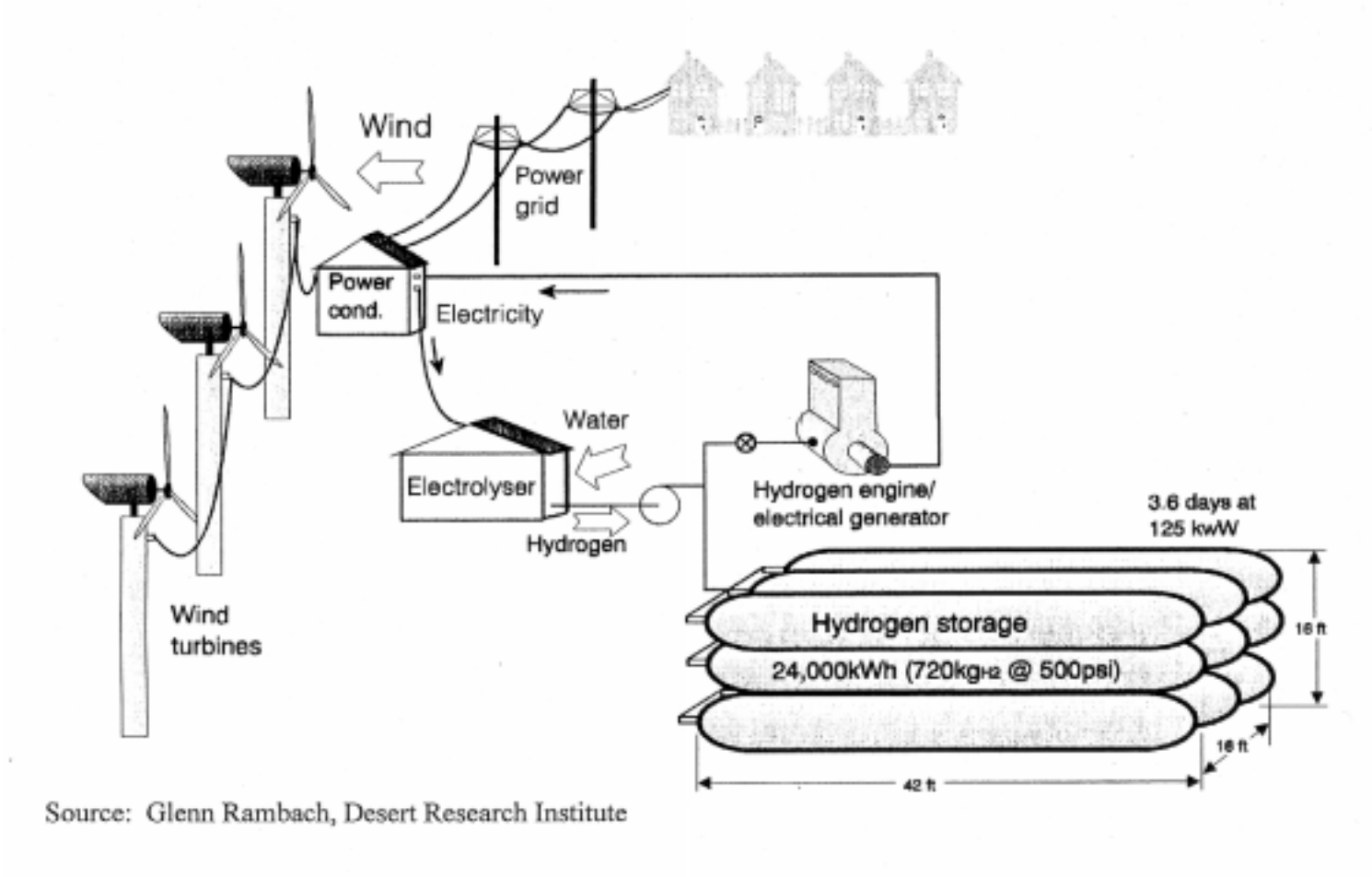
- **High cost**
- **Cadmium considered toxic material**



Flywheels (Electromechanical Battery)

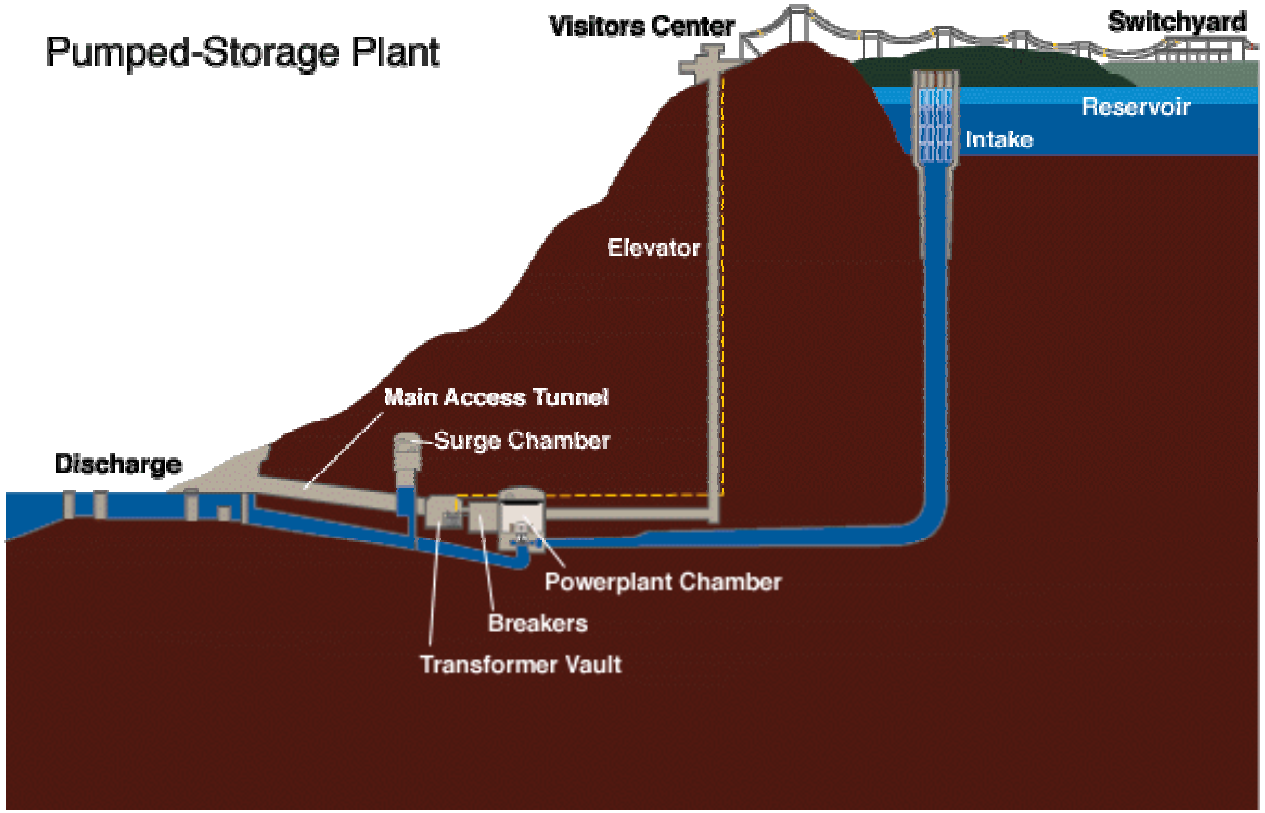


Hydrogen Cycle Energy Storage



Source: Glenn Rambach, Desert Research Institute

Pumped Hydro



Conclusions

- Energy storage is often the key factor in implementing isolated renewable energy hybrid power systems.
- Before choosing the type and size of energy storage, the objective must be considered.
- In most cases, batteries are still the most cost-effective energy storage technology.
- Further R&D on advanced storage technologies will increase the range of options available to designers of village power systems.