



National Wind Technology Center

Energy Storage for Hybrid Village Power Systems

Village Power '98
Technical Workshop

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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?

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

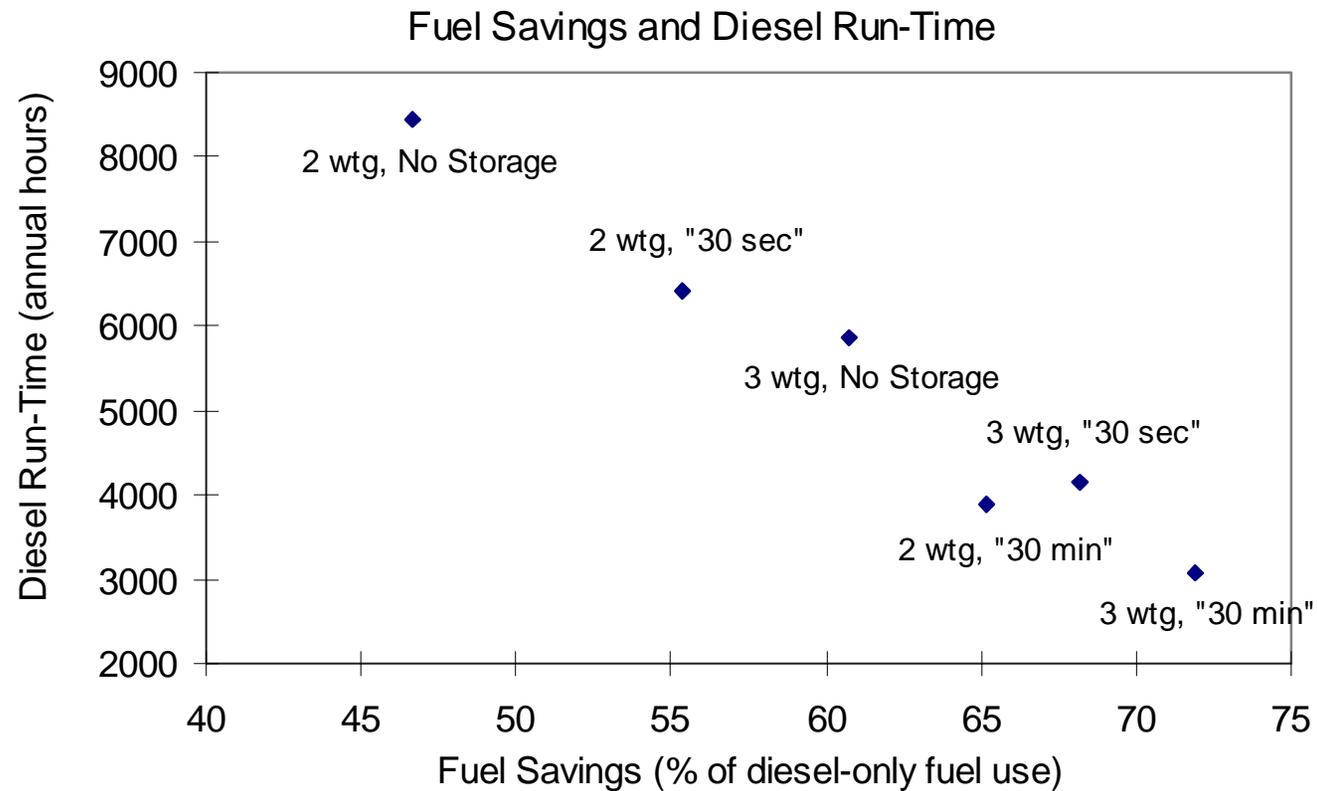


Hybrid Power Systems Use Various Amounts of Energy Storage Depending on the Objective

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. <ul style="list-style-type: none">• 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. <ul style="list-style-type: none">• 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. <ul style="list-style-type: none">• 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. <ul style="list-style-type: none">• 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



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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**

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

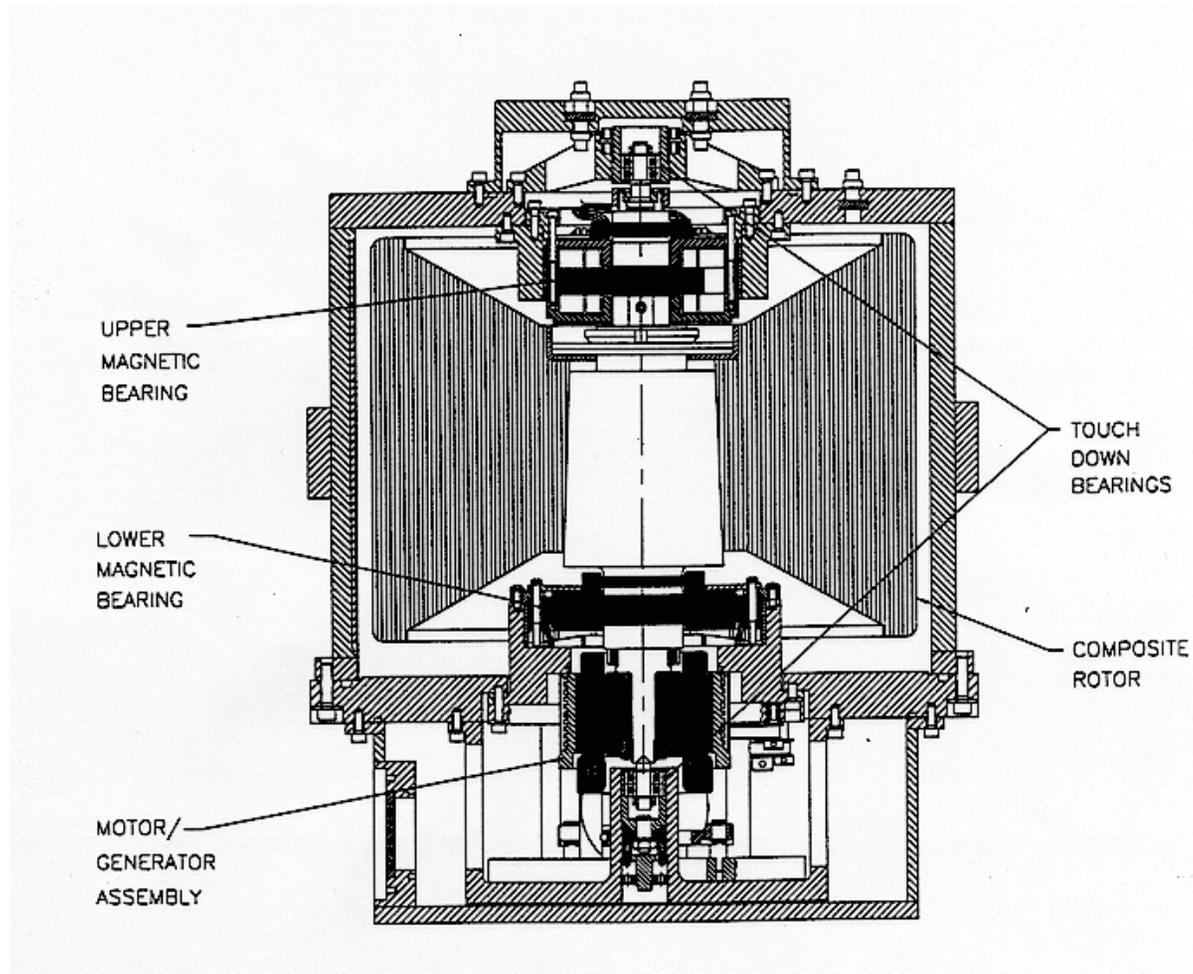


Ni-Cd Battery

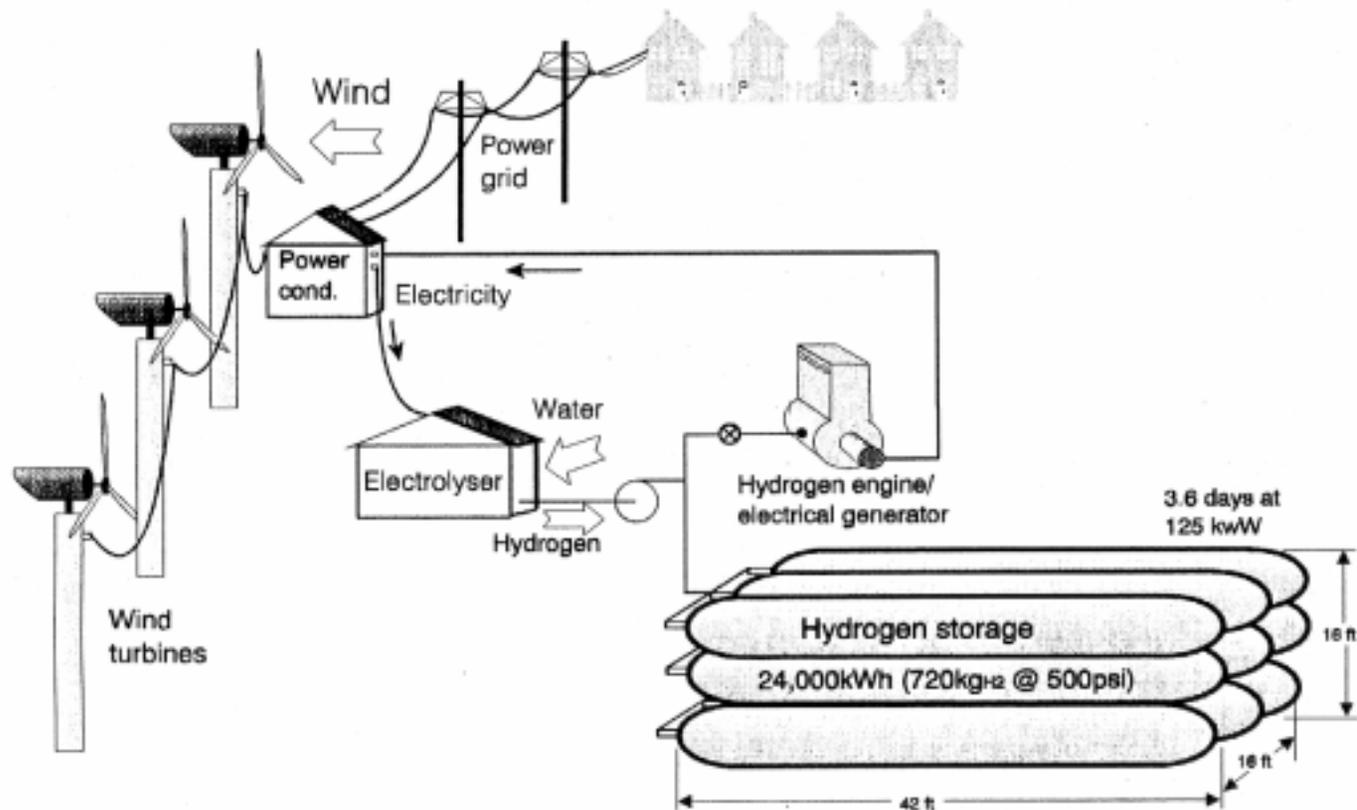
- **Long life**
 - **Tolerant of abuse**
 - **High energy and power density**
 - **Good low temperature performance**
 - **Relatively light weight**
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- **High cost**
 - **Cadmium considered toxic material**



Flywheels (Electromechanical Battery)

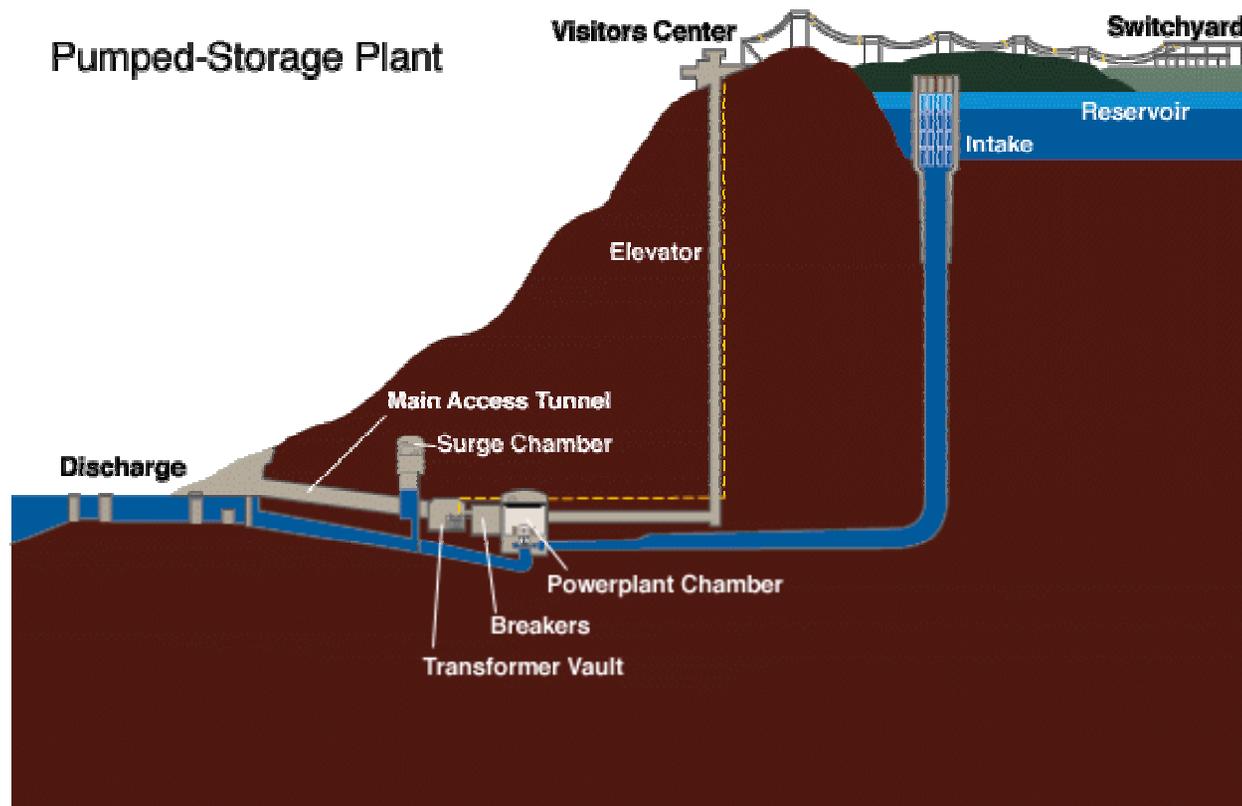


Hydrogen Cycle Energy Storage



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.