Underwater energy (uwenergy@mit.edu)

Goals

Macro scale project

- Enough power to light up an abandoned oil rig (10-100X 100W light bulbs = 10-100kW)
- Extreme reliability (~ 10 years)
- Completely autonomous
- Easy to deploy

Micro scale project

- To power electronic fish tags by capturing the kinetic energy of an animal swimming through the water
- Sensors on fishes

Background

Price of electricity

- US average in 2003 is about 8 cents per kWh (1kWh = 3.6MJ), 12 cents in MA
  http://www.eia.doe.gov/neic/brochure/electricity/electricity.html

Suggested reading

- Energy Numbers
  http://www.ocean.washington.edu/courses/envir215/energynumbers.pdf

Known failure modes

- Corrosion: submarine lifespan is 30 years with overall reconstruction every 3-5 years

Alternative energy sources

Wind

- 40% wind-to-mechanical efficiency
- 85% mechanical-to-electrical generator efficiency
- 35% overall efficiency
  http://www.uaf.edu/coop-ext/publications/freepubs/EEM-01352.pdf
- Power output of 2MWe (Mega Watts electrical, unit of output electric power), grouped into farms of 200MWe
- 25% load factor (capacity factor?)
- 4-25m/s wind speed, max output at 12-25m/s
- 50m long blades, foundations require hundreds of cubic meters of reinforced concrete
  http://www.uic.com.au/nip38.htm

Light

- **Photovoltaic cells: 15% capacity factor, 15% light-to-electric efficiency**
  http://www.uaf.edu/coop-ext/publications/freepubs/EEM-01352.pdf

Fossil fuels

- **Conventional power plant thermal efficiency: 30-40%**
  http://www.uaf.edu/coop-ext/publications/freepubs/EEM-01352.pdf

Energy sources:

Types of currents

- **Technical background and terminology**
  http://www.irbs.com/bowditch/pdf/chapt09.pdf

Tidal flows

- **2-3m/s are equivalent to wind speed over 200km/hr (56m/s)**
- **1MWe turbine reduces from 60m in wind to 20m in water**
  http://www.uic.com.au/nip38.htm
- **Sergius Narrows, AK, 6kt = 3m/s (1kt=0.514m/s), 12hr period**
- **Gillard Pass, BC, 7kt, 12hr period**
- **Gorge-Tillicum, BC, -7kt, 24hr period**
- **Nakwakto, BC, 10kt, 24hr period**
- **Sechelt, BC, 11kt, 24hr period (?)**
- **Seymour, 11kt, 24hr period (?)**
  http://www.sailwx.info/tides/tidemap.phtml

Characterization of surface ocean currents

- **Accessible from oil rigs (depth, speed?)**
  http://oceancurrents.rsmas.miami.edu/index.html

Oceanic currents (oceanic circulation)

- **Accessible from oil rigs (depth?)**
- **South equatorial current, 2.5kt = 1.3m/s, east coast of South America**
- **Gulf Stream (Florida current), 2-4kt = 1-2m/s**
- **Kuroshio Current, 3mph = 1.3m/s, Japan**
  http://www.irbs.com/bowditch/pdf/chapt32.pdf

Alternative power generators

Aquantis

- Colvos passage, Florida (check)
- 30m horizontal axis turbine
- Nine turbines span 500m, 100m deep
- 750kW per turbine X 9 = 6.75MW = 13GWh/yr
- 22% capacity factor
- Turbines rated at 1.6m/s
- Production of energy from hr 3 to hr 10 (0.6m/s minimum) out of 12 hr half period; max speed at 1.6m/s; total power is 35.4MWh/day
- Usable flow is 14,000 cubic meters per second
- Cost (operation & maintenance) 2-3 cents per kWh

  http://iere.org/energy/Vashon-Summary.pdf

Blue Energy Power System

- 7m ducted vertical axis turbine, 250kW X 31 = 7.75MW

  http://eqsa.org/powerline/plarticle.cfm?article=60

Abacus Controls

- 3m dual horizontal axis turbines, 90kW X 60 = 5.4MW

  http://iere.org/energy/Vashon-Summary.pdf

Marine Current Turbines

- First offshore (3km, check!) tidal current turbine
- Operating now for two years
- 300kW in 5.5kt (2.7m/s)

  http://www.marineturbines.com/mct_text_files/Press%20Release%20MCT%2016%20May%2003%20V2.0.pdf

Upper bound: Conversion of water speed into power

$$P = F_{drag} \cdot V$$

$$F_{drag} = \tfrac{1}{2} \rho C_d A V^2$$

$$P \propto V^3$$

- Momentum flux = integral (n dot ρ V) V dA
- Average energy = ½ ρ g (A squared)
- ρ (U squared) = momentum per area?

Design of oscillatory systems

Advantages

- No seals

Problems

- Fatigue

Design of rotary systems

Advantages

- **Ease of design**
- **High energy efficiency**

Problems

- **Failure of seals (reliability)**

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