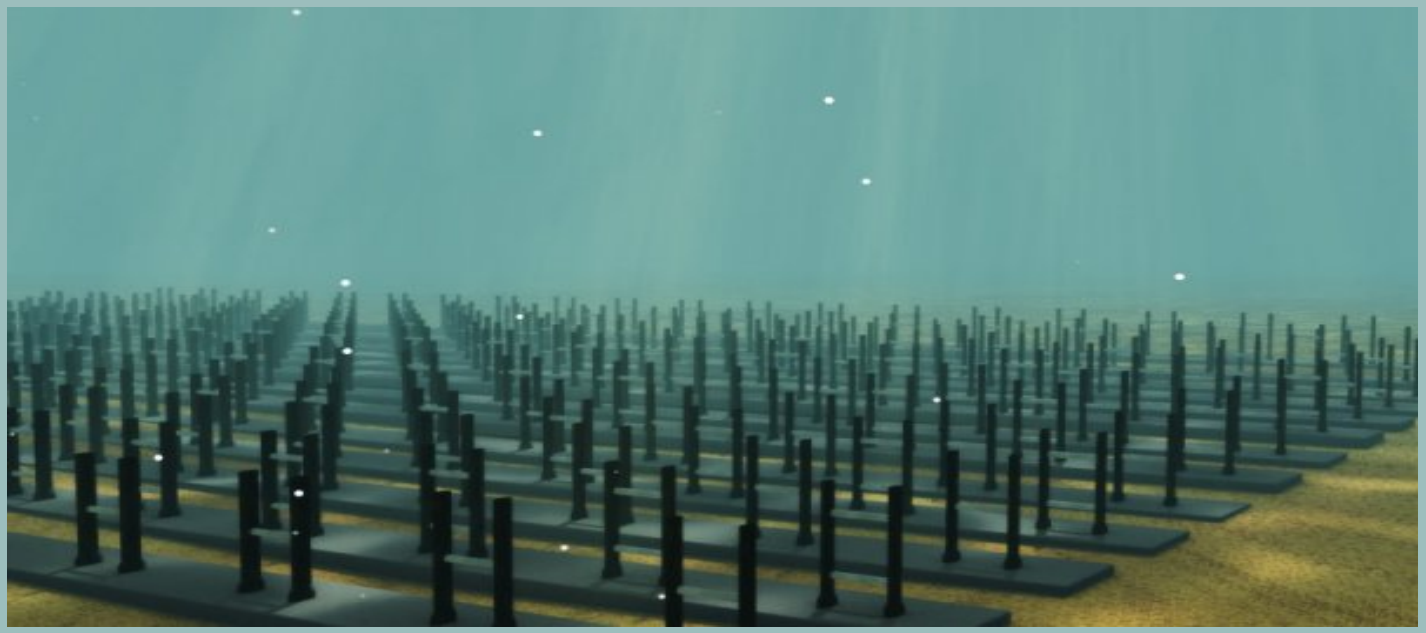


Credit: Omar Jamil

The VIVACE device

(Vortex Induced Vibration Aquatic Clean Energy)

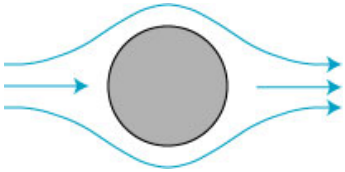
Victor Darphin
04/20/2015

THE VIVACE DEVICE

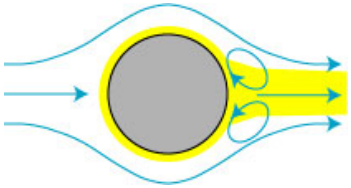
- Patented by the University of Michigan
- Convert water currents into electric power
- Uses Vortex Induced Vibrations to move cylinders up and down and then convert this motion into electricity
- Clean and renewable source of energy
- Widely available resource:
  - Estimate for the energy contained in water currents and tidal variations: from 280,000 TWh to 700,000 TWh
  - Worldwide electricity generation: 16,000 TWh
  - Close to a large part of the world population

FLUID VORTICES

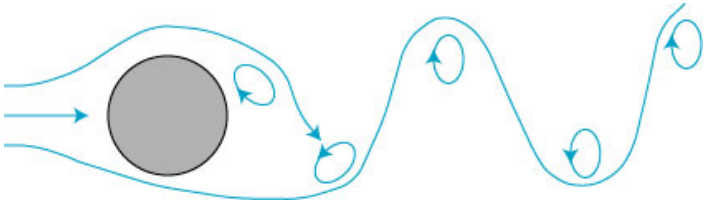
- Region of a fluid flow rotating around an axis (straight line or curve)
- Occurs when a rigid body is interacting with a fluid flow



Friction creates an area with a lower flow speed around and after the cylinder



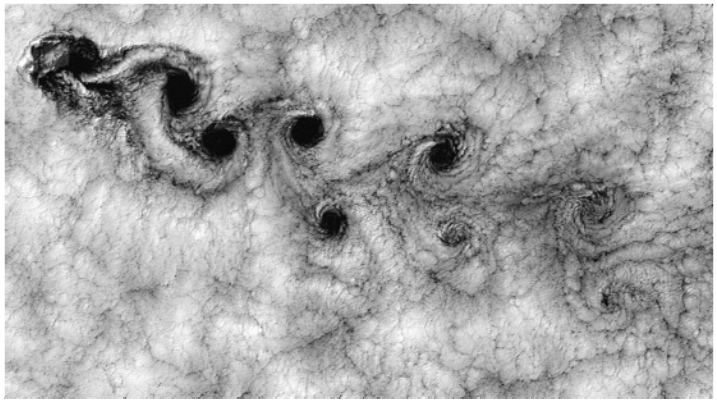
Vortices are formed at the boundary between the slow and fast flow areas



Vortex shedding: vortices get pushed downstream by the flow, in the form of a **vortex street**

Figures: http://skullsinthestars.scientopia.org/2008/12/06/turning-a-problem-into-a-solution-aquatic-clean-energy-from-vortex-induced-vibration/

VORTEX SHEDDING



- The vortex street is asymmetrical
- The vortex shedding is oscillating

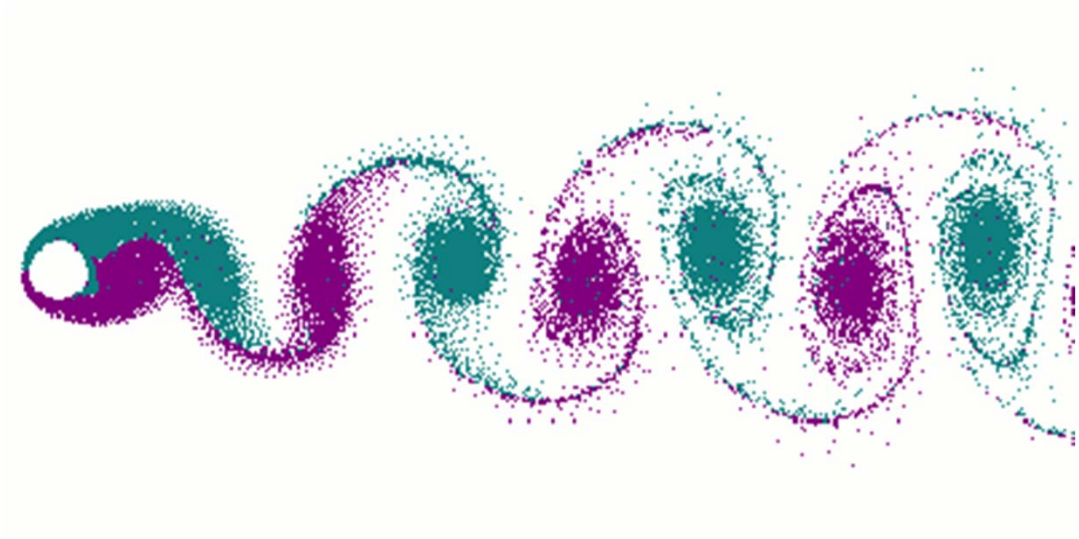
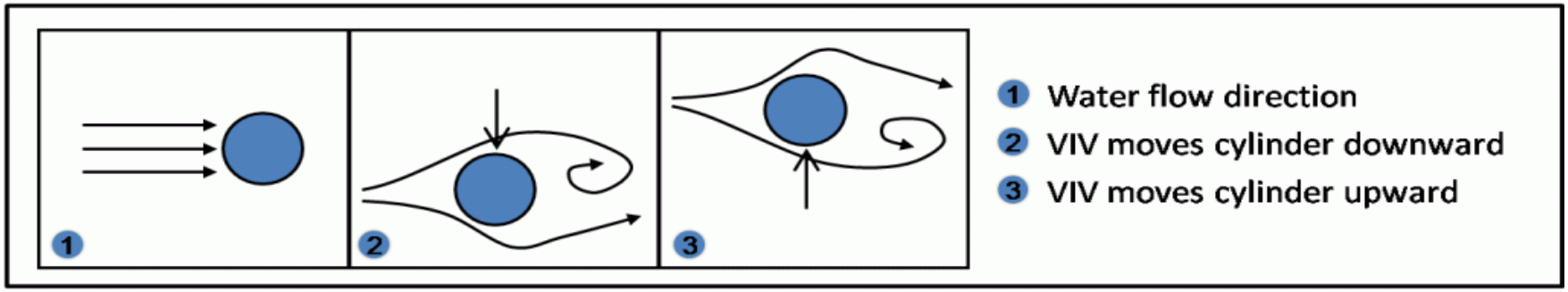


Photo by the NASA
Animation by Cesareo de La Rosa Siqueira.

VORTEX INDUCED VIBRATIONS

- Periodic motion produced on the rigid body by the vortex shedding
- Very well know phenomenon
- Can cause damage to civil, marine, aero and mechanical engineering applications
- VIVACE uses it to make a cylinder move and harness power from that motion



http://www.vortexhydroenergy.com/

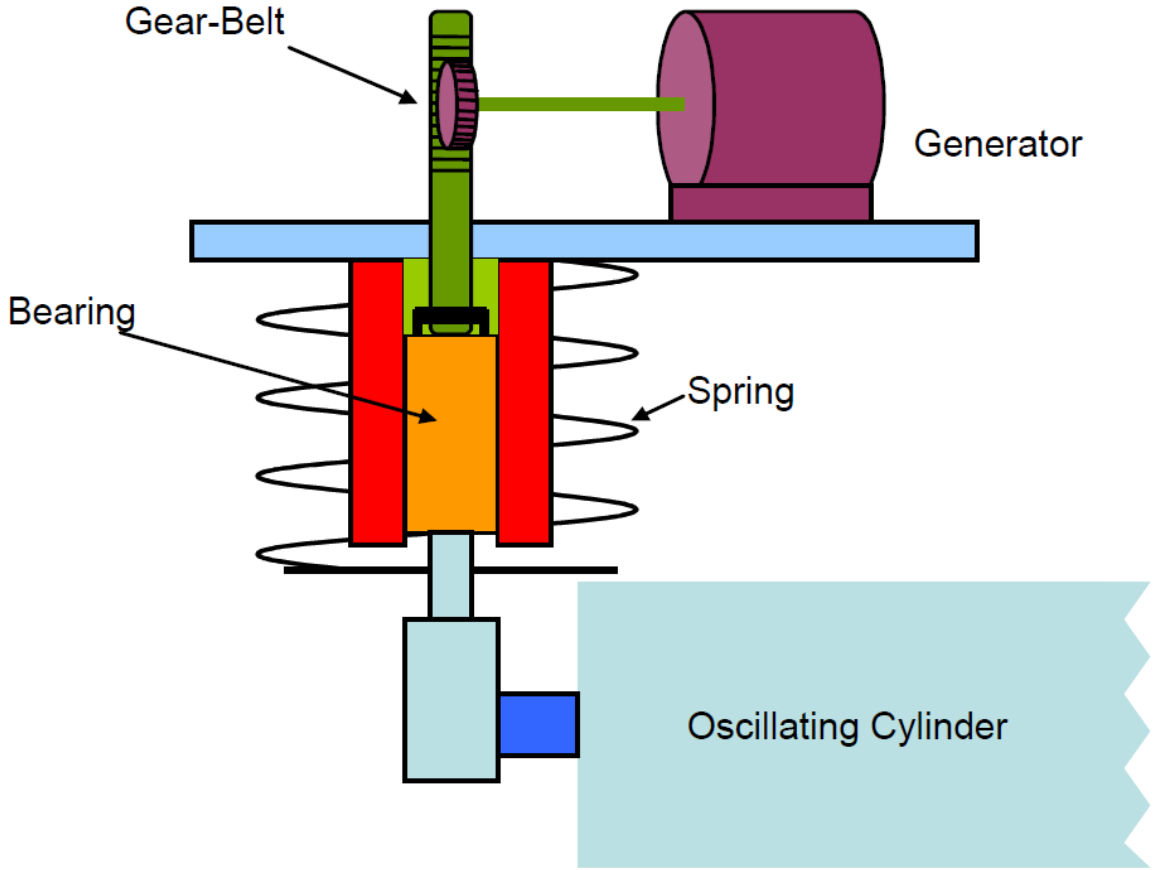
NON LINEAR RESONANCE

- Inherently related to VIV
- In a broad range around the natural frequency, vortex shedding locks into the oscillation frequency of the cylinder
- Synchronization of the oscillations from the flow and the cylinder
- Non linear resonance phenomenon
- Self-limited in amplitude

POWER EXTRACTION

First design: gear and generator

The up and down motion of the cylinder drives the rotation of the gear which in turn drives the generator



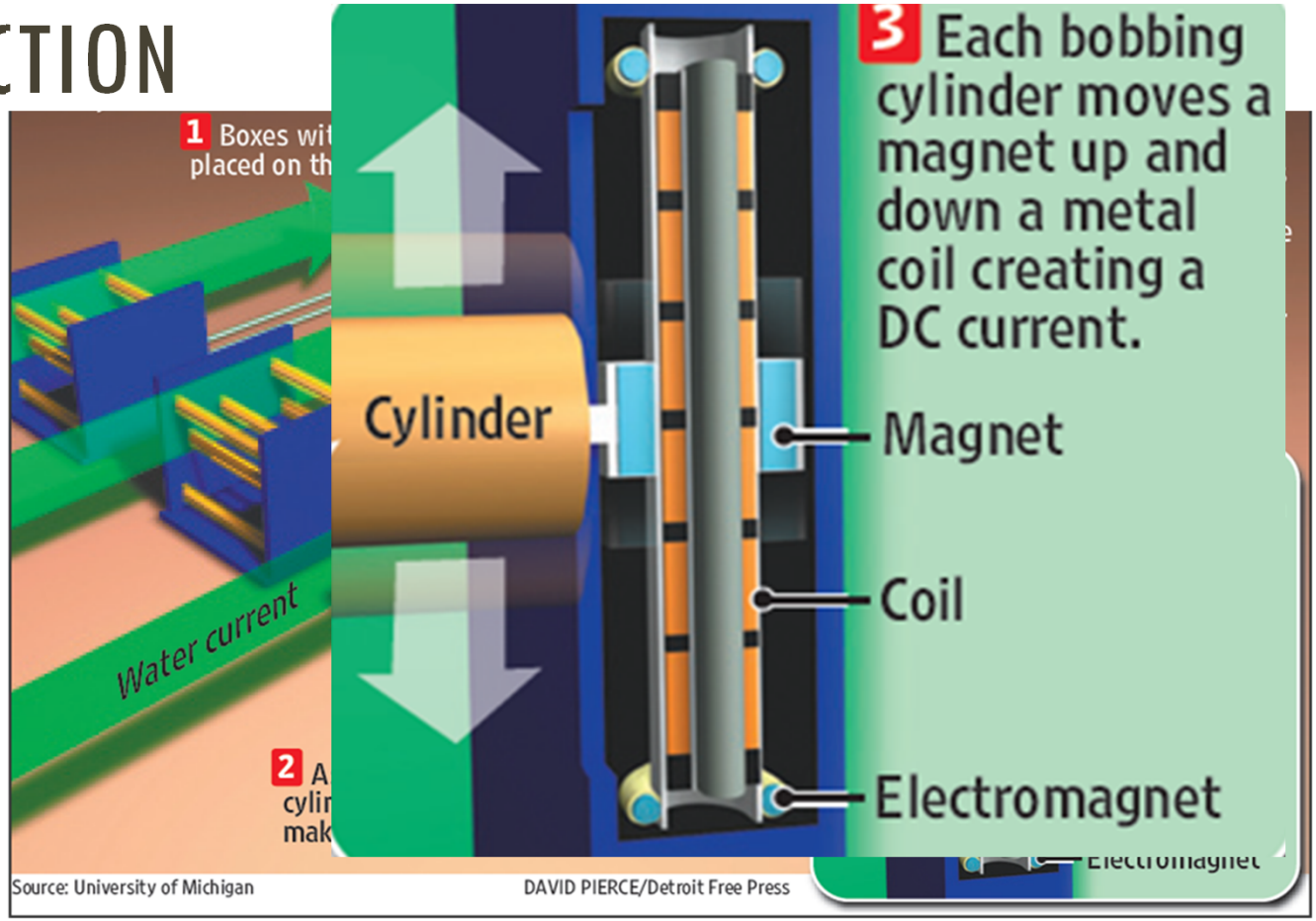
Picture from: VIVACE (Vortex Induced Vibration Aquatic Clean Energy): A New Concept in Generation of Clean and Renewable Energy From Fluid Flow, *Michael M. Bernitsas; Kamaldev Raghavan; Y. Ben-Simon; E. M. H. Garcia*
Proc. ASME. 47470; Vol 2: Ocean Engineering and Polar and Arctic Sciences and Technology:619-637.January 01, 2006

POWER EXTRACTION

Second design:

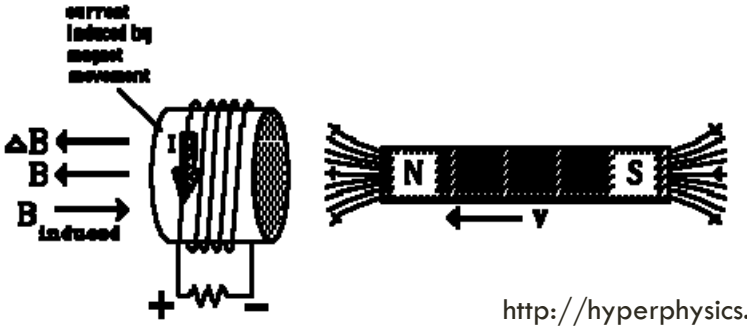
magnet and coil

Need for an DC/AC converter



http://www.vortexhydroenergy.com/

DC GENERATION



http://hyperphysics.phy-astr.gsu.edu/

Faraday's law of induction:

$$\Phi_B = \iint_{\Sigma(t)} \mathbf{B}(\mathbf{r}, t) \cdot d\mathbf{A} \ ,$$

EMF produced by a variation in the magnetic field: $\mathcal{E} = -\frac{d\Phi_B}{dt}$

The EMF creates a current in the coil (which creates a magnetic field opposing $\frac{d\Phi_B}{dt}$)

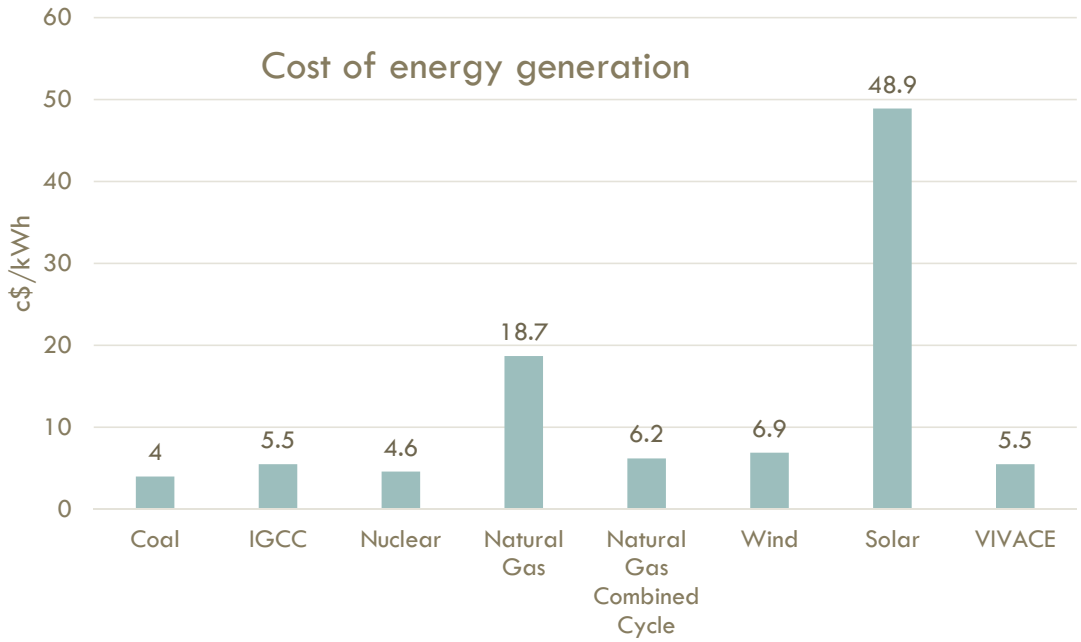
ADVANTAGES OF THE VIVACE DEVICE

- Uses a widely available renewable resource
- Can tap into water currents as slow as 0.5 knots (0.58 mph) against 4 knots for conventional turbines. Most water currents in the US are slower than 3 knots.
- The cylinders move slowly (about a cycle/sec) → not a threat for marine life
- Modular, scalable and flexible (size of cylinders and number of modules)

SOME FIGURES

Power	**100 MW**	**100 kW**
D x L	1m x 20 m	4 m x 0.2 m
Cylinders	13 094	328
Efficiency	22% (upper limit: 36.63%)	22%
Water Depth	20 m	5 m
Footprint volume	10,359,953 m3 (on 128 acres)	1,962 m3
Weight (including foundation)	148,714 tons	100 tons

BENCHMARKING



IGCC: Integrated Gasification Combined Cycle

- Similar cost as conventional generation
- Good volume energy density compared to other wave energy converters
- Better weight energy density compared to other wave energy converters

APPLICATIONS

- Costal generation (more than half of the US population lives within 50 miles of the coast)
- Rivers generation (with low impact on the flow)
- Provide renewable power for various applications:
  - Desalination (to provide drinking water from the sea)
  - Water pumping
  - Underwater sensors
  - Offshore facilities

DOE REQUIREMENTS FOR OCEAN ENERGY CONVERSION DEVICES

- High energy density
- Unobtrusive to navigation
- Not obstruct other use of expensive coastal real estate
- Friendly to marine life and the environment
- Have low maintenance
- Be robust
- Have a minimum life of 10-20 years
- Meet life cycle cost targets

CONCLUSION

- Clean and renewable energy
- Widely available source
- Complies with DOE requirement for ocean energy conversion devices
- Can serve a wide range of applications
- Reasonable cost
- Still in R&D phase

THANK YOU!

Questions?

References (in addition to footnotes):

- http://vortexhydroenergy.com/
- Bernitsas M.M., Raghavan K., Ben-Simon Y., Garcia E. M. H., "VIVACE (Vortex Induced Vibration Aquatic Clean Energy): A New Concept in Generation of Clean and Renewable Energy from Fluid Flow", OMAE 2006; and Journal of Offshore Mechanics and Arctic Engineering, ASME Transactions, Nov. 2008, Vol. 130, No. 4, pp. 041101-15.