Voith Hydro

- 110 kW prototype.
- To be tested in S Korean waters in late 2010.
- 1 MW version to be produced in 2011 for trials at EMEC.

Atlantis Resources Corporation

- Australian group with links to Norway and the UK.
- Bi-directional, single-rotor machine, 18m diameter.
- Atlantis AK1000 1 MW turbine to be tested at EMEC in 2011.

MeyGen

http://www.bbc.co.uk/news/uk-scotland-24100811
viewed September 2013

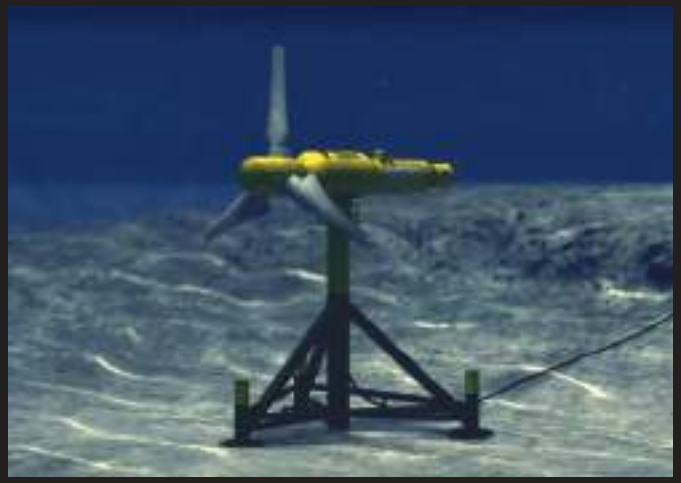
- Consent obtained for installation in the Pentland Firth, between Orkney and Scottish mainland.
- AR1000 turbine has a rotor diameter of 22.5 m, weighs 1,500 tonnes, and is rated at 1MW.
- Aspiration: 400 turbines generating 398 MW.

"August [2017] proved to be a world record month, providing enough energy to power 2,000 Scottish homes from just two turbines [700 MWh]. "

(David Taaffe, Project Director as quoted in the Independent)

Alstrom

Deployment at EMEC



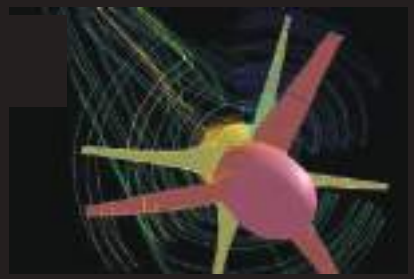
- 22 m long nacelle
- weight 150 tonnes
- 3 pitchable blades, 18 m dia.
- buoyant to allow towing
- deployed in a water depth of about 40 m
- rotates around vertical axis
- reached full nominal
- power of 1 MW in January 2013 at EMEC
- endurance and reliability tests underway

ESRU/ Nautricity: CoRMaT

- Contra Rotating Marine Turbine (CoRMaT).
- 2.5 m diameter contra-rotating turbine prototype.
- Tow-tank tested and sea trialled in the Firth of Clyde and Sound of Islay.

CoRMaT characteristics

Two closely spaced dissimilar rotors move in opposite directions.



Reduced Capital Cost

- No expensive moorings or pilings required
- Commercially viable even at small generating scale

Reliability

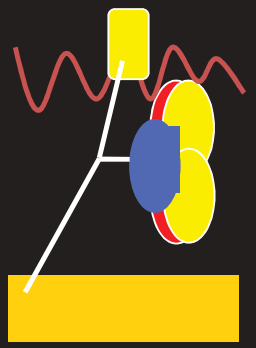
- Direct drive generator eliminates need for gearbox
- No complex blade pitch control

Ease of Maintenance

- Easy to deploy and recover
- Small number of simple sub-assemblies

Efficient

- Increased energy capture compared to single rotors
- Always optimally oriented to tidal flow
- Increased deployment density due to decreased wake effects

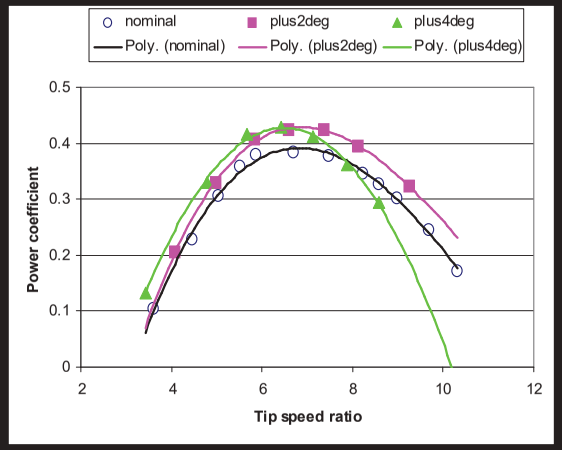


Wide operating envelope

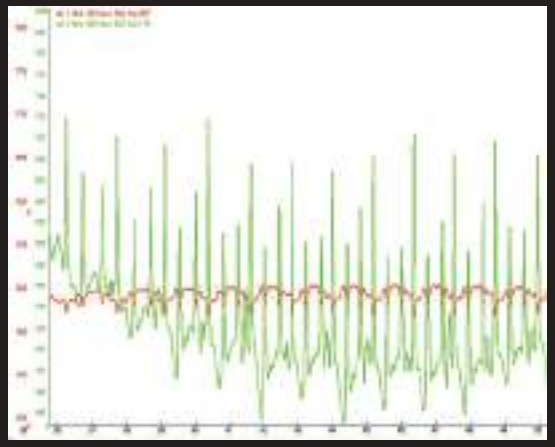
- Suitable for deployment in water depths from 8- 500m where maximum tidal energy harvest is likely

CoRMaT test results

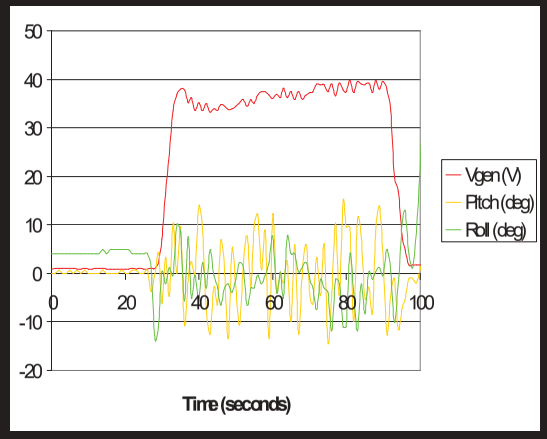
1: Tow-tank tests confirm neutral buoyancy



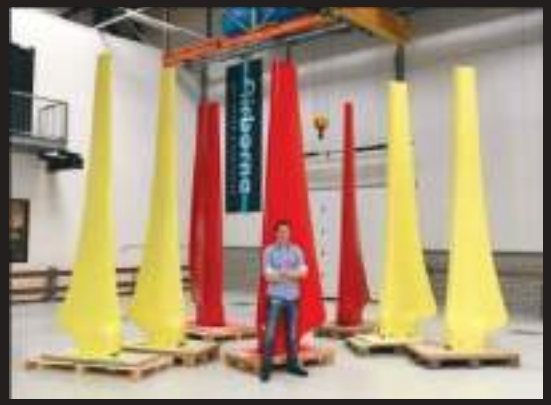
2: Sea trials confirm dynamic stability ...



3: ... and enhanced power output



CoRMaT 750 kW device manufacture



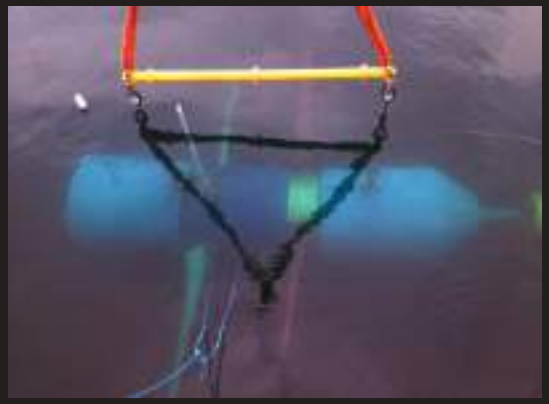

- GFRP Blades – Airborne, Netherlands
- Contra-rotating radial PMG – Smartmotor, Norway

CoRMaT assembly and pre-testing





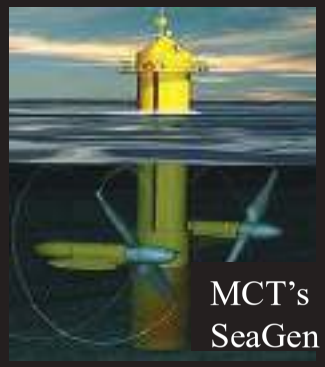

CoRMaT deployment at EMEC – September 2013



Challenges

… oscillating aerofoil driving hydraulic accumulators

… horizontal axis turbine evolved from wind technology

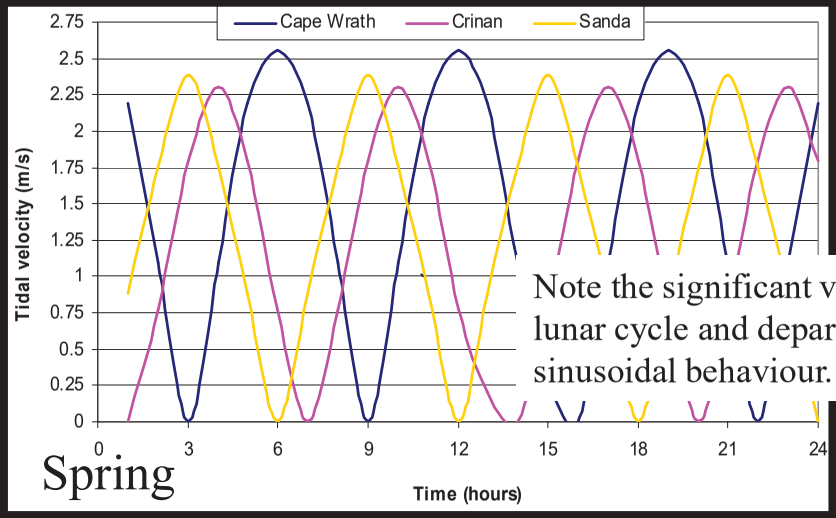


… contra-rotation, tethered

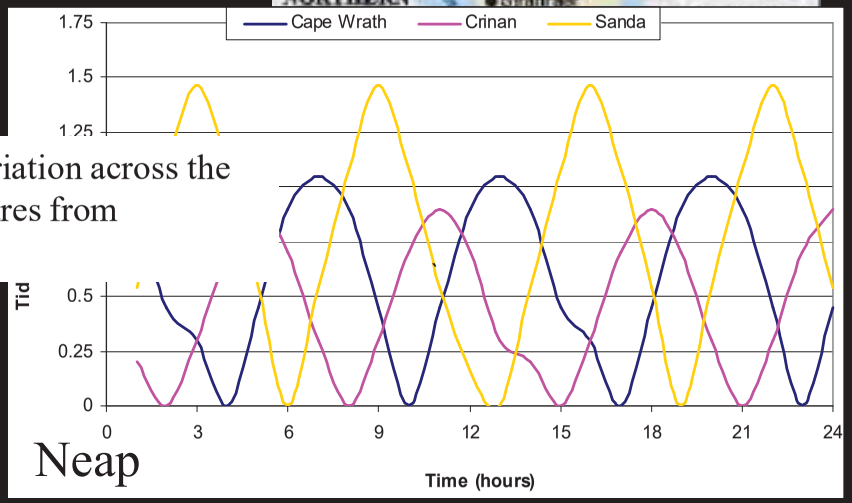
- Reduce capital cost.
- Limit corrosion and abrasion.
- Maintenance and safety issues.
- Power take-off at low rotation speed.
- Gearing reduction/elimination.
- Power transmission/grid access.
- Land access and use.
- Phased operation of different sites.
- Maritime & aquaculture impact.
- Overcome vested interest.
- Key question: given the daily and monthly velocity variations, can phased tidal stream sites be employed to provide predictable, firm power?

Synchronised tidal stream farms

- 3 Scottish coastal sites investigated:
  - Cape Wrath
  - Crinan at the Sound of Jura
  - Sanda off the Mull of Kintyre
- Hourly stream velocities taken from Admiralty charts



Note the significant variation across the lunar cycle and departures from sinusoidal behaviour.

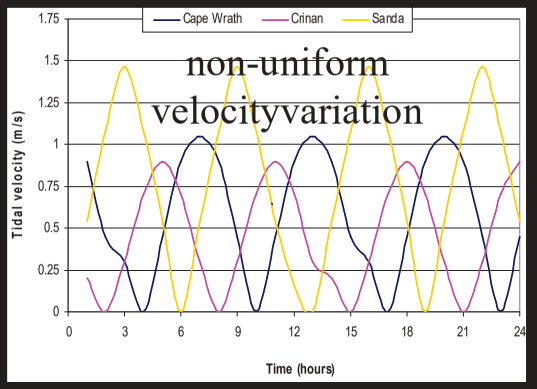


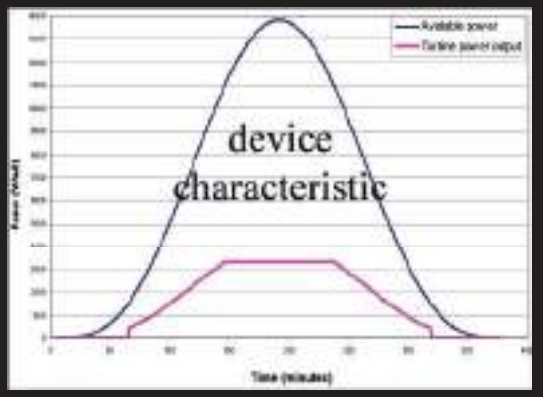
Spring and Neap tide daily velocity variations at the 3 sites

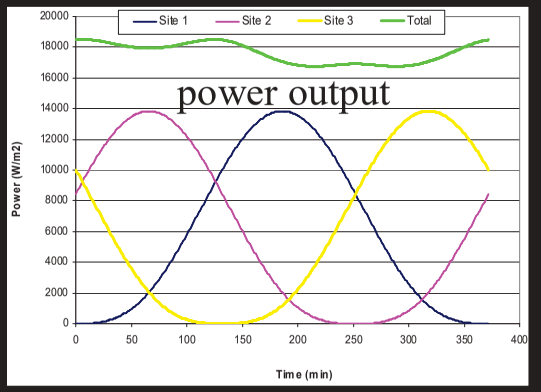
Synchronised power output

Assumptions:

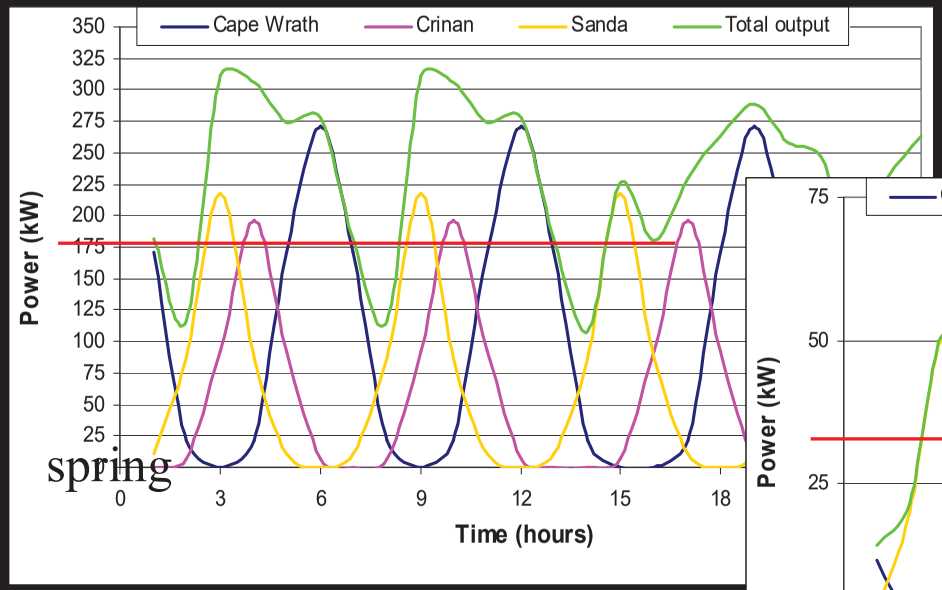
- Turbines operate in an open stream environment.
- Dynamic loading ignored (as caused by velocity shear, stream misalignment or wave action).
- Turbulence effects ignored.
- Turbine has a cut-in stream velocity, with enforced idleness at slack water.
- Above a rated stream velocity power is held constant.
- Device sized for maximum power extraction.
- Available power given by $P = \frac{1}{2} \rho A V^3$ (ρ the fluid density, A rotor swept area and V stream velocity).
- Turbine $C_p = 0.3$, cut-in @ 1 m/s, cut-out @ 2.5 m/s).

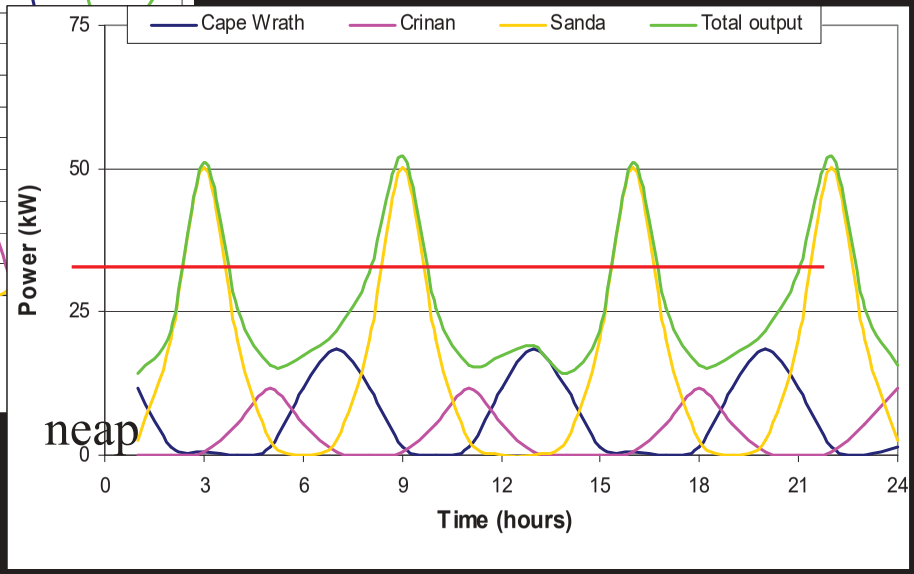






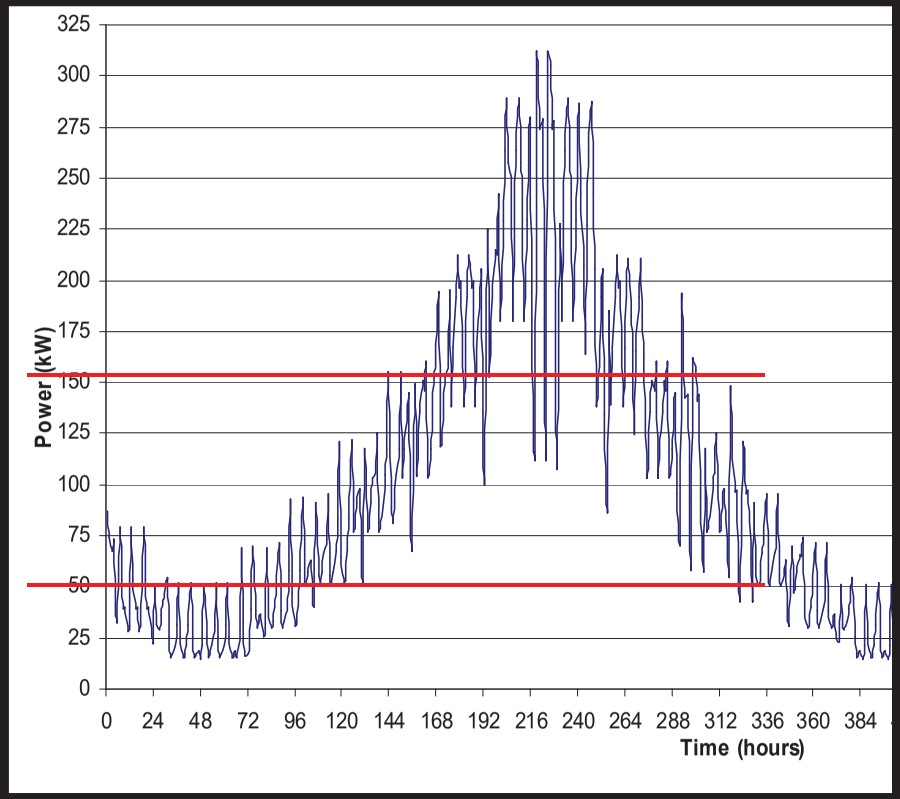
Site and aggregate power output





- Spring tides: a significant base load is evident - about 1/3 of peak.
- Neap tides: the outputs are much lower at about 1/4 of peak.
- Changes between successive cycles are evident - Sanda is cycling at a higher frequency, a phenomenon that will reverse at another point in the lunar cycle.

Power output fluctuation over the lunar cycle



Options:

- size turbines to restrict the maximum output to that experienced during neap tides;
- size turbines for the average monthly output and introduce other sources of energy to meet the shortfall;
- size turbines for the spring tide condition and introduce long term (weekly) energy storage so that the excess capacity during near-spring tides can be stored for later use.

- Variation between spring and neap tide power production shown here over a half-month period.
- Fluctuations in output due to the lunar cycle affect all sites simultaneously.

Conclusions

- Some level of base load provision can be achieved via the phased operation of dispersed tidal current power stations.
- Difficulties arise due to the non-uniformity of site velocities.
- The natural variations that occur between successive tidal cycles (daily and monthly) produce a significant irregularity in aggregate power output.
- The predictability of tidal power output may be regarded as a major asset in energy supply management.
- The twice-daily cycle may be smoothed by the use of hydraulic pumped storage, or the phased operation of conventional hydro power plant.
- The lunar cycle induced variation in power output may be accommodated by complementary sources of energy or energy storage.
- Linking widely dispersed sites will place extra demands on the network.
- Accurate data are needed to predict the performance of systems of this kind.

- See tutorial questions for typical tidal range and stream calculations.