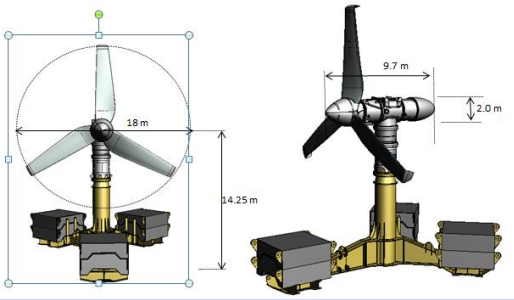
Province of Nova Scotia Industrial Expansion Fund

FUNDING PROPOSAL FOR AR-1500 TIDAL ENERGY PROJECT (Excerpt)

Community & Environment

Industrial Expansion



Technology Leadership & Innovation

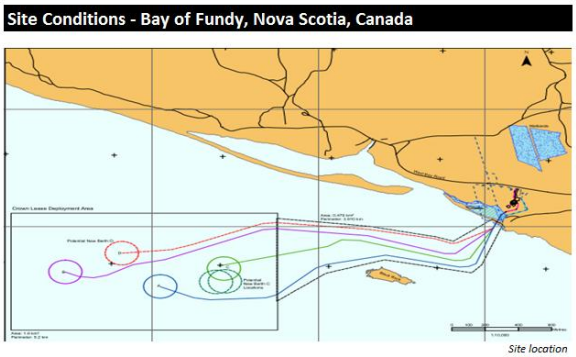
October 2013

ATLANTIS
RESOURCES CORPORATION

LOCKHEED MARTIN

IRVING

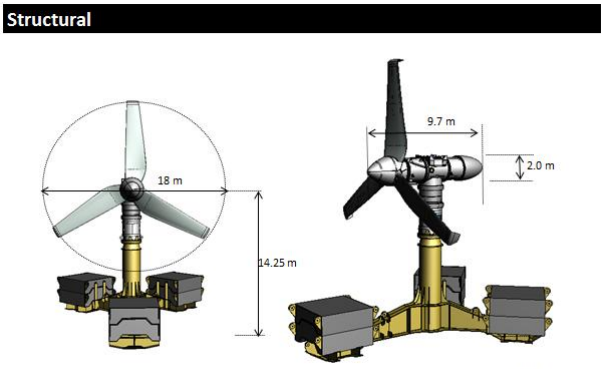
Project



Site location

Supported by the NSIEF, Atlantis, together with its partners Lockheed and Irving Shipbuilding Inc. ("Irving"), will design, fabricate, install and operate a next generation customized full scale (1.5MW) tidal turbine, the AR-1500, at the FORCE facility in Nova Scotia. Design, assembly, installation, and O&M will be conducted using local labour including that based at Irving Shipbuilding's Woodside facility and Lockheed Martin's Dartmouth facility. The AR-1500 will be the most powerful single rotor set tidal power turbine ever built, generating grid-compliant predictable power to up to 1,500 local homes. It will be designed to withstand the uniquely powerful flow conditions that will be experienced in Bay of Fundy, and the system will incorporate a wide range of new innovations in marine power generation, including:

- The design and operation of new HV, LV and fibre-optic wet-mateable subsea connectors;
- The design and sea-trials of a new high flow, heavy weather nacelle launch & recovery system;
- A new control software platform to maximize power output given daily & seasonal flow velocity angle variations;
- An active yaw drive system, unique Yaw Drive Module and active/seasonally programmable nacelle heading control.
- Revolutionary fail-safe multiply redundant blade pitching system



Key Dimensions

Once the AR-1500 is proven at FORCE over a c.1 year period, data from the site will be used to apply for and secure requisite environmental leases and necessary permits for a larger turbine array which could eventually extend to 200 turbines or more (300MW = 20% of Province electricity demand) in the Bay of Fundy. Turbine system operational data will also be used to underpin commercial array economic predictions – the basis for access to project debt markets. Upon project sanction, at the end of the Detailed Design Phase, commercial tidal turbine systems will be assembled using local fabrication and assembly yards (which could include Irving's Woodside facility). Component supply will be supported by a Nova-Scotia focused Canadian supply chain managed by Lockheed Martin Canada in their role as systems integrator, which we predict will be at a highly cost effective price per unit indexed to order volume. This is the catalyst the Canadian

marine power sector needs to become a commercial, investable reality; proven technology capable of withstanding the harsh flow conditions present in the Bay of Fundy, and an established local supply chain to provide competitively priced tidal turbine systems to both the domestic and export markets.

3 Proposed Development

3.1 Background

Atlantis designs and manufactures horizontal axis tidal current turbines. These turbines convert the kinetic energy of tidal current induced water flows – such as those powerful flows found in the Bay of Fundy – into rotational kinetic energy of a rotating blade set and then via a gearbox, powertrain and generator, into electrical energy that can be exported to shore and dispatched

predictably to grid. Atlantis' first commercial-scale 1MW tidal turbine, the AK1000™, was deployed in Scotland in August 2010,

Figure 2.1: Precursor device: Atlantis' 1MW AK1000 turbine, deployed in Scotland, Summer 2010

The energy generation potential of tidal power within the province of Nova Scotia is estimated to be in excess of 2GW or enough to power 2 million residential Canadian homes. However, there are presently no turbine system designs that exist on the commercial market capable of economically harnessing this abundant, predictable and sustainable renewable energy resource. Proving the technical and economic feasibility and the environmental performance of the AR-1500 system could stimulate the creation of a new indigenous industry in the Province – leading to job creation and the use of the existing highly skilled labour and maritime infrastructure that is already well established in the Province, given its long maritime history.

3.2 Objectives

Atlantis, together with its partners Lockheed Martin Canada (LMC) and Irving Shipbuilding (Irving), intends to design, construct, install and operate a next generation full scale (1.5MW) tidal turbine, the AR-1500, customised to survive the harsh conditions present in the Bay of Fundy and deployed at Atlantis' awarded berth at the Fundy Ocean Research Centre for Energy (FORCE) facility in Nova Scotia. Design, assembly, installation, and O&M will be conducted using local labour based at Irving's Woodside facility and LMC's Dartmouth facility.

The AR-1500 design and deploy program in the Bay of Fundy is expected to:

- Deliver a commercial scale tidal turbine system that is tested, commissioned and operated in the Bay of Fundy, thus stimulating the local economy and existing supply chain (marine component manufacture & assembly, materials & composites, offshore construction, shipping and logistics) within Nova Scotia by catalysing the development of a marine power industry around a turbine system capable of economic energy extraction when deployed at commercial scale;
- Research, develop and prove the design function and operation of a 1.5MW tidal turbine (rated at 3m/s) integrating five innovative features:
    - New high voltage, low voltage and fibre optic connectors facilitating fast, safe and diverless subsea connection of the nacelle to the power export cable;

    - a new nacelle installation and recovery system (establishing a reliable installation and operations and maintenance (O&M) regime for commercial deployment and operation of tidal turbine nacelles in the fast flowing waters of the Bay of Fundy);
    - Yaw drive system for nacelle rotating (360o capable without a cable management system using slip ring technology) and active/programmable nacelle heading to optimise annual power yield;
    - Revolutionary fail-safe multiply redundant blade pitching system;
    - ROV operated hydraulic pin actuated nacelle recovery.
- Generate the impetus for a commercial scale, multi hundred megawatt tidal power project and a tidal industry supply chain to support development of this sector Nova Scotia.

Having been awarded the fourth berth at the FORCE test facility in the Bay of Fundy in 2011, Atlantis Resources Corporation promptly incorporated a Nova Scotia-headquartered subsidiary – Atlantis Operations (Canada) Limited – for the purpose of developing the site and project described herein. We are applying for this NSIEF funding as a Nova Scotia company fully incorporated in the Province.

The next generation AR1500 turbine will be a single rotor set turbine with active yaw and auto heading capability that will adjust turbine heading on change of tides and angle of current direction seasonally. The exact design of the foundation structure depends on the specific site characteristics within our berth, water depth and seabed geotechnical conditions. Mounted on top of the mono-pylon is a proprietary male/female gravity stab arrangement which allows the turbine nacelle to be removed from the gravity base foundation structure for maintenance without the need to recover the foundation, reducing lift weight and therefore required vessel specification.

This NSIEF project will facilitate advanced research and development of the world's most powerful, single rotor set, open ocean tidal turbine. In particular NSIEF funding will facilitate a programme of turbine structure research beyond Atlantis' current budgeted capability, facilitating the development of a system that has been designed specifically for the Bay of Fundy and the uniquely harsh marine environment we expect to encounter.

The NSIEF programme will incorporate a suite of new cutting edge system innovations, including:

- The design and operation of new HV, LV and fibre-optic wet-mateable subsea connectors;
- The design and sea-trials of a new heavy, high flow weather nacelle launch & recovery system;
- A new control software platform to maximize power output given daily & seasonal flow velocity angle variations;
- Revolutionary multiply redundant fail-safe blade pitching mechanism;
- An active yaw drive system, unique Yaw Drive Module and active/seasonally programmable nacelle heading control.

Key line items where NSIEF funds will match our private capital include:

- Detailed structural nacelle research and design work, lifecycle simulation, environmental performance measurements and component testing.
- Blade/rotor research, materials science research, blade shape design and testing.
- Component procurement, system manufacture and system assembly and commissioning
- Drive train control research, testing and verification.

- Male & female stab (Nacelle/Foundation interface) manufacture and design.
- Research and Technical labour costs.
- Environmental baseline monitoring, environmental impact research, acoustic signature monitoring and ongoing performance reporting program.
- Commissioning, operations and maintenance costs (including control system monitoring, construction vessel, ROV intervention and associated labour costs).

In addition to the AR1500 turbine build and deployment, future tidal energy products may be developed in parallel, notably tidal installation vessel design, nacelle deployment and retrieval system, improved electrical infrastructure for power export and subsea power and data connection systems. Complimentary and related research programmes focusing upon environmental impacts mitigation and assessment, inter-array turbine interaction and turbulence modelling, efficiency, rotor performance and future cost reduction analysis (water to wire) may also be facilitated via collaboration with academic institutions, as demonstrated by the existing MoU between Dalhousie University and Atlantis.

3.3 Overview of the Technology

Atlantis' commercial-scale tidal turbine platform architecture, AR1500, as illustrated in Figure 2.3.1 and 2.3.2 below, will comprise:

1. The turbine nacelle, housing all of the electro-mechanical systems including the blades, a yaw drive system that affords rotation of the nacelle and the stab mechanism designed to connect the turbine to the top of the support pylon;
2. Support pylon between the stab connection and the foundation; and
3. Foundation structure to secure the turbine to the seabed. A Gravity Based Structure (GBS) type foundation is shown below.

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The turbine's nacelle will support a 3-bladed rotor at one end of the nacelle. The blades will be mono-directional blades designed to cater for tidal flow in one direction, with the nacelle then

being rotated up to 360 degrees about the vertical axis at the exchange period between each tide, to then capture the tide in the opposite direction via an active yaw system.

The blades will measure 8m in length thus providing a swept area of 18m in diameter (including a 2m diameter hub). The blades will have a minimum clearance from the seabed of 5m.

The support pylon measures 2m in diameter, and is c.8m long. Mounted on top of the pylon will be a stab arrangement which allows the turbine to be removed from the GBS for maintenance. Between the stab arrangement and the horizontal turbine nacelle will be mounted on the yaw drive system used for aligning the rotor to tidal flow.

The exact design of the foundation structure will depend on the specific deployment location and geotechnical properties of the seabed at the FORCE facility. The GBS for the harsh environment at European Marine Energy Centre (EMEC), Scotland, weighs c. 1,300 tonnes in air once fully assembled.

When fully assembled, the turbine will stand approximately 23m from the seabed to the tip of the blade when in the 12 o'clock position.

Once installed at FORCE, the AR1500 will work autonomously. Sensors will enable the turbine to ascertain the incoming water speed. The blades will commence rotation when the speed of the water reaches 0.6m/s. The rotation of the blades simultaneously rotates a shaft connected to a permanent magnet generator (PMG) which converts the kinetic energy of rotation into electricity. The hardware and software activate the pitching system to modulate energy capture – a system which offers multiple redundancy in the event of hardware or software (or power) failure. A diagram of the power train used in the nacelle can be seen in figure 2.3.2 below.

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Rated power will be achieved at a water speed of 3m/s. Once this water speed is exceeded the control system and pitching system will deliberately adjust torque in the system to reduce rotational rpm maintaining a constant rated power output until the water speed slows below 3m/s again. The AR1500 will use both pitching and a passive stall system to stop rotor rotation

at speeds that exceed 3.4 m/s. There is a fail-safe mechanical brake on the shaft in the event of over-speed or loss of grid supply and an electrical brake is used during operation via the converter.

A detailed specification sheet is included as *Appendix 1.*

3.4 Advantages Over Other Technologies

Whilst there are many technologies at the pre-commercial stage of development, currently no device exists for commercial scale tidal energy extraction from the Bay of Fundy. Of those technologies currently under development, the AR1500 is closest to deployment.

The primary advantage of the AR1500 turbine over other technologies tested or scheduled for testing in Nova Scotia (Open Hydro) is that it is substantially more efficient at converting power from the water column (for example Atlantis turbine is potentially>200% more efficient than the Open Hydro device[1]). This increase in efficiency arises from the bladed nature of the Atlantis device, while the Open Hydro has opted for open centre ducted devices with commensurately lower efficiency. (Information is not available publicly about the design or expected efficiency of the Minas/MCT unit to be installed at FORCE, or whether design work on a device has commenced specifically for a unit capable of withstanding the forces present in the Bay of Fundy).

Consequently, Atlantis believes it can offer a substantially (>40%) lower cost of energy than the above incumbent devices, while providing an unparalleled level of robustness, reliability and deploy/retrieval ability, forged through our experiences of deployment internationally.

It has been widely reported in the media that there have been technical failures and delays associated with the recent and planned deployments of other devices, and this has been blamed in part on the exceptionally challenging conditions in the Bay of Fundy including tidal induced flow rates of up to 11 knots (5.5m/s).

Atlantis believes that to overcome these challenges new products need to be brought to market, as they are currently not available; namely a passive stall rotor system (incorporating a self-stall blade design and multiply-redundant fail-safe pitching system to prevent over speed or over-torque), and pioneering nacelle installation, retrieval and intervention systems. The design of a currently unavailable yaw drive unit will include mechanical aspects as well as control hardware and a software platform to allow the precision alignment of the device after installation on the GBS, periodic alignment corrections to account for seasonal changes in the tide flow and 180±20° realignment of the device between ebb and flood of the tide cycle. Without development of the envisioned component parts that will be used in the deployment of the AR1500 at FORCE, Atlantis believes that exploitation of the Canadian tidal energy market will be significantly limited.

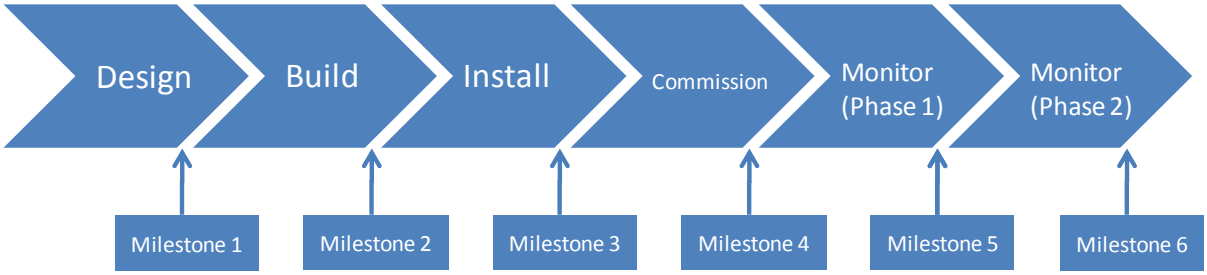
The AR1500 will be custom designed to withstand the harsh environmental conditions that have been recorded in the Bay of Fundy and to increase expected nacelle intervention (scheduled and unscheduled maintenance) intervals. Further, the AR1500 system will be a non-ducted horizontal axis turbine. Research conducted on ducted versus non-ducted turbines has concluded that ducted turbines are not viable in harsh open ocean conditions and not

[1] *Analysis based on publicly available data. Open Hydro unit generates 1MW at 4m/s, while the AR-1500 unit will generate 1.5MW at 3m/s. Since power goes as the cube of the water speed, this indicates a 3- fold increase in efficiency).*

economically viable in commercial scale tidal farm applications. Research completed by the Department of Mechanical Engineering at the University of Victoria in British Columbia and published in the IEEE Oceanic Engineering Society Newsletter in December of 2010 concluded that: 'for large scale generation, designs which use the base pressure effect (ducted turbines) are less suitable due to their inherently lower efficiency' (we would be happy to provide the NSIEF with copies of the relevant academic papers on request).

3.5 Project Plan and Milestones

The FORCE project falls into six stages as indicated below. Commencing in October 2013, design and build will take approximately 15 months, followed by 3 months to install and commission the device and a further 12 months of operation and monitoring through to December 2016.



A detailed project plan has been prepared for the project considering all aspects of the design, build, deployment and operation of the device, and we would be happy to share this with you on request. A summary of this plan is shown in Figure 2.5 below.

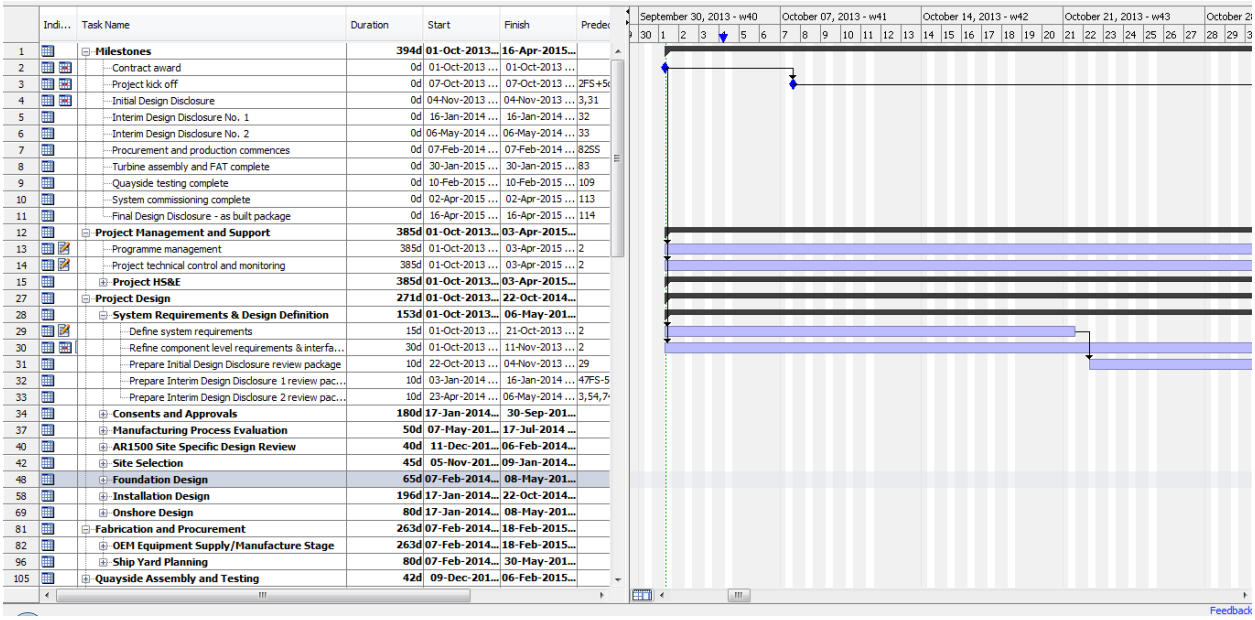


Figure 2.5: Top level schedule for AR1500 Full Scale 1.5MW commercial tidal turbine deployment at FORCE

A full copy of the project programme is included as *Appendix 2*.

Inter-relationships between individual work packages necessary for the successful completion of the project inclusive of all balance of plant are mapped out and the team is ready to promptly commence works.

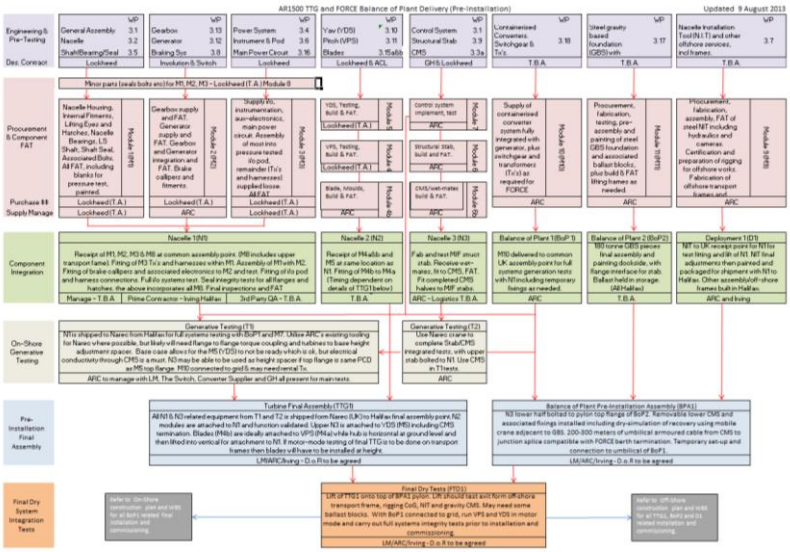


Figure 2.6 AR1500 Balance of Plant Delivery