arpa·e
CHANGING WHAT'S POSSIBLE

SHARKS—**S**ubmarine **H**ydrokinetic **A**nd **R**iverine **K**ilo-megawatt **S**ystems

PROJECT DESCRIPTIONS

National Renewable Energy Laboratory – Golden, CO

A Computer Tool to Control Co-Design Hydrokinetic Energy Systems - $1,200,000

The National Renewable Energy Laboratory will expand its open-source Wind Energy with Integrated Servo-control (WEIS) toolbox to include control co-design capabilities of tidal and riverine hydrokinetic turbines. Based on the OpenFAST computer tool, the new toolbox will be expanded to include hydro-elastic-servo modeling capability for tidal and riverine energy systems.

The University of Michigan – Ann Arbor, MI

*RAFT: **R**econfigurable **A**rray of High-E**f**ficiency Ducted **T**urbines for Hydrokinetic Energy Harvesting - $3,900,000*

The University of Michigan proposes the RAFT concept as a solution for hydrokinetic energy harvesting. The proposed RAFT, made up of multiple micro-turbines, has a modularized architecture with reconfigurable units, making it adaptable to different applications and marine environments. The innovative new turbine designs, along with distributed load control and regulator concepts, significantly reduce the levelized cost of energy. In-situ real-time optimization-based control and distributed continuous system health monitoring optimize RAFT's features to achieve performance, resiliency, reliability, and cost targets. Multidisciplinary engineering efforts with extensive modeling, iterative optimization, control co-design, and experimental validations will mitigate identified technical risks.

Aquantis, Inc. – Santa Barbara, CA

Tidal Power Tug - $4,500,000

The Tidal Power Tug is a tidal hydrokinetic turbine with a vertical-axis yawing spar buoy and a horizontal-axis parallel-flow rotor. Applying control co-design techniques, the turbine will achieve stable, safe operation in all sea conditions with unprecedented cost performance gained by use of novel materials, vertical mass-buoyancy distribution, high power-to-weight ratio, efficient deployment/retrieval, adaptive controls for blade pitch and shear compensation, and advanced analytical tools for efficient O&M. These factors will result in high turbine up-time. The turbine will be designed for power delivery to remote and local grids. It will operate autonomously, with a remote supervisory control and data acquisition computer providing data analysis and operator input to the onboard controller. The control system will be able to prioritize maintaining the lowest cost of energy, increasing component life and maximum available energy.

Westergaard Solutions, Inc. – Houston, TX

HydroMINE: Simple, Modular and Scalable – $2,000,000

HydroMINE is a disruptive and elegantly simple system with an internal propeller driven by pressure from a stationary hydrofoil structure to a separate, internal flow stream. The internal propeller drives an ordinary electric generator. The size of the stationary HydroMINE hydrofoil structure is comparable to an equivalent ordinary rotor of the same swept area producing a similar amount of energy. HydroMINE is safe for the marine environment, and extremely robust. It has a low maintenance cost, resulting in a lower cost of energy. It is manufactured with steel plates with the existing supply chain and integrates easily with ordinary marine structures for flexible deployments. The design is scalable from a community size (kW) to utility level (multi-MW), making HydroMINE immediately commercially relevant.

University of Washington – Seattle, WA

Confinement-Exploiting Cross-Flow Turbine Arrays –$2,000,000

The bottom, sides, and surface of rivers and tidal channels confine water flow, which significantly alters the operation of river and tidal turbines. When the area that a turbine array presents to the flow is an appreciable fraction of the channel cross-sectional area, changes to the flow increase array power output and overall efficiency. When the turbines are in close proximity, mutual interactions can further increase power output. The University of Washington proposes a control co-design process that combines advances in turbine control strategies, hydrodynamic configurations and array geometry optimization to capitalize on the unsteady non-linear fluid dynamics. The team will focus on cross-flow current turbines, which are well-suited to achieving high confinement in river and tidal channels. The project aims to demonstrate a significant step-change up in efficiency with a step-change down in cost of energy.

University of Virginia – Charlottesville, VA

Bio-Inspired Renewable Energy (BIRE) for Highly-Efficient Low-cost Riverine Hydrokinetics - $3,500,000

The University of Virginia's BIRE system aims to generate energy from the river environment through real-time control of pairs of out-of-phase oscillating hydrofoils placed into oncoming flow. The river flow causes the two foils to oscillate in opposite directions. A novel power conversion mechanism converts the oscillatory motion of the foils to unidirectional rotary motion to harvest the energy. BIRE will have minimal en vironmental impact and easily connect to local electricity grids. The project proposes a control co-design methodology to optimize the BIRE system, opening up energy generating opportunities in riverine environments, not previously catered to with current technologies.

SRI International – Menlo Park, CA

MANTA: Reliable and Safe Kite Energy System - $4,202,231

Underwater kite systems offer the promise of energy capture from tidal power with minimal structural costs. Current approaches are not scaled for small communities, however. SRI's proposed Manta kite system is simple and based on the payout and reel-in pumping action of a kite. A novel transmission integrated into the kite tether efficiently couples kite motion directly to compact rotary generators with only one rotary bearing required. A small pump will allow kites to sink in the event of a storm, passage of a large vessel, or wildlife migration. The Manta kite can produce power with minimal structure and installation costs, achieving a levelized cost of energy four times less than that of rotary turbines. The Manta kite system will support remote microgrids, as well as larger systems.

University of Alaska Fairbanks – Fairbanks, AK

Material and Cost Efficient Modular Riverine Hydrokinetic Energy System - $3,331,361

The University of Alaska Fairbanks' concept employs BladeRunner's floating generator housing and tethered turbine to create a Hydrokinetic Turbine (HKT) system that has low capital and operating costs and is well suited for community co-design. The turbine is coupled to the generator by a flexible torsion-cable that transmits mechanical power while allowing the turbine to deflect around debris. This technology combines three significant new and innovative solutions to reducing remote riverine HKT levelized cost of energy: (1) the highly material-efficient BladeRunner architecture increases swept area per equivalent mass by 130% over the base case; (2) the implementation of C-Motive's novel electrostatic generator to efficiently convert low speed mechanical rotation into grid-voltage electricity; and (3) the shore-based deployment and retrieval method enabled by the BladeRunner modular design.

Emrgy, Inc. – Atlanta, GA

Performance Enhancement of Hydrokinetic Arrays Using Reliable, Low-Cost Dynamic Components - $3,613,020

Emrgy, Inc., is applying control co-design and design for operation to develop a highly innovative solution to low-cost, riverine and tidal-based clean energy power generation. The project will implement (1) new control system actuators able to modify in real-time the hydrokinetics and geometry of the turbine and the flow across the rotors; (2) novel power conversion hardware to optimize mechanical to electrical efficiency; and (3) turbine- and system-level control algorithms employing novel coordination, optimization and machine learning techniques to manage both turbine and array hydrodynamic features in real time. Successful implementation of the technology will significantly reduce the levelized cost of energy.

Ocean Renewable Power Company, Inc. – Portland, ME

Optimized Hydrokinetic Systems - $3,676,997

Using control co-design methodologies and design for operation techniques, Ocean Renewable Power Company, Inc. (ORPC) proposes a novel hydrokinetic energy system that identifies dynamic couplings between turbine subsystems and components to optimize system mass and performance. The new systems will be deployed in arrays. The project includes hydrodynamic testing of model-scale turbines to guide and validate the new concepts and the construction of a larger-scale turbine, with sensors embedded during manufacture to validate structural design. The team will perform open water testing and measurements of performance and loads by mounting the turbine in an open water test frame, based on the ORPC RivGen® Power system. It will demonstrate prognostic health monitoring and active load control approaches.

Littoral Power Systems, Inc. – New Bedford, MA

Control Co-design and Co-optimization of a Transformational Cost-Efficient Hydrokinetic Energy Turbine System - $3,677,507

Littoral Power Systems, Inc., proposes to design, fabricate, and test a novel in-current hydrokinetic energy turbine system that substantially reduces levelized cost of energy compared with the state of the art. The team will use a control co-design engineering framework to characterize and numerically optimize the system for minimized LCOE through three parallel activities: (1) minimize and balance key design-driving loads and trade active versus passive techniques to control dynamics on soft moorings; (2) analyze dynamic interactions among system components to determine where functions can be integrated and controls applied with greatest efficacy; and (3) analyze key cost drivers for deployment, retrieval, and operations to determine where marine robotics techniques can be integrated to have the greatest impact on lowering costs and/or increasing system availability.