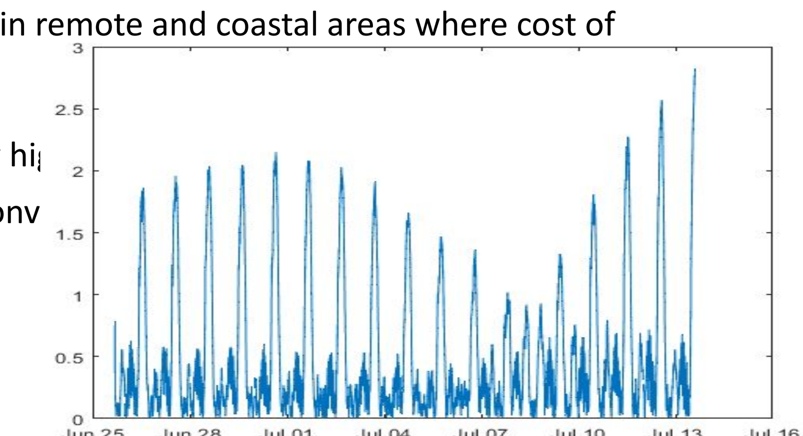
Introduction of a Full Bridge Converter with Maximum Power Point Tracking Control for Efficient Tidal Energy Harvesting

Emma Geon, Roshan Kini, Linnea Weicht, Benjamin Roberts, Alex Turpin
Pacific Northwest National Laboratory

MPPT control and an optimized full bridge converter demonstrate efficient tidal power conversion over a range of input voltages

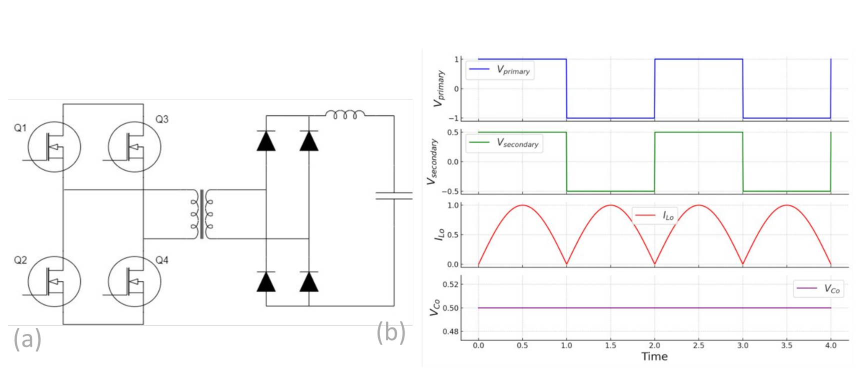
1. The Challenge: Tidal Power Efficiency

- Tidal energy, with its high predictability, presents an opportunity for carbon-free, sustainable power, particularly in remote and coastal areas where cost of electricity is high.
- Tidal energy is characterized by hi… challenge for efficient power conv…



Tidal speed in meters per second over two weeks during the summer of 2022 at the inlet to Sequim Bay, Sequim, WA.

2. Converter Topology



Full bridge converter (a) topology (b) switching waveforms including the primary voltage alternating between positive and negative source voltage, and the secondary voltage scaled by the turns ratio, the output inductor current (I_{Lo}) displaying characteristic ripple, and the output capacitor voltage (V_{co}) maintaining a relatively constant value with minor ripple.

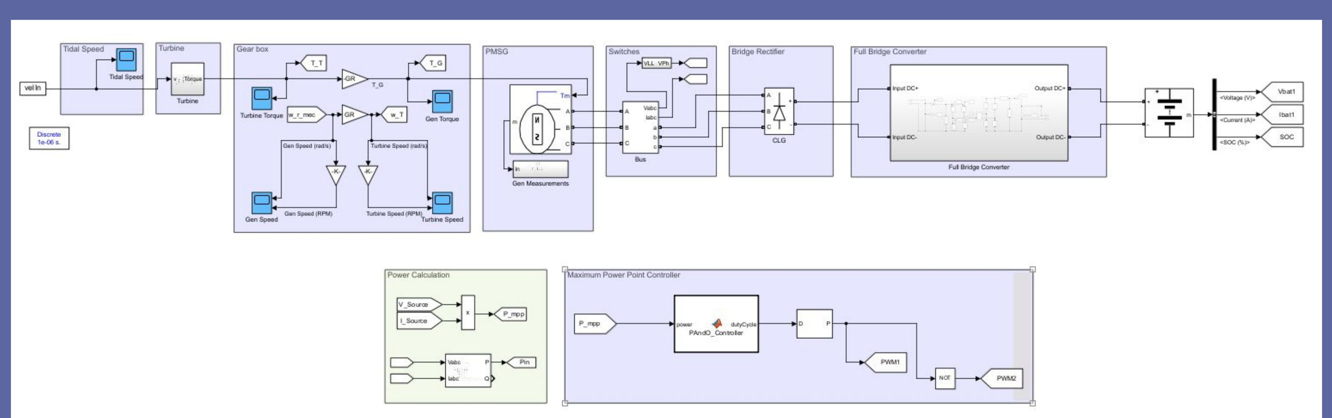
- Four switches in H-bridge configuration.
- High-frequency switching transformer producing square wave voltage across the transformer
- AC voltage is produced, rectified and filtered resulting in stable DC voltage.
- Output voltage is regulated by adjusting the duty cycle or phase shift of PWM signal controlling the switches.

3. Control Design

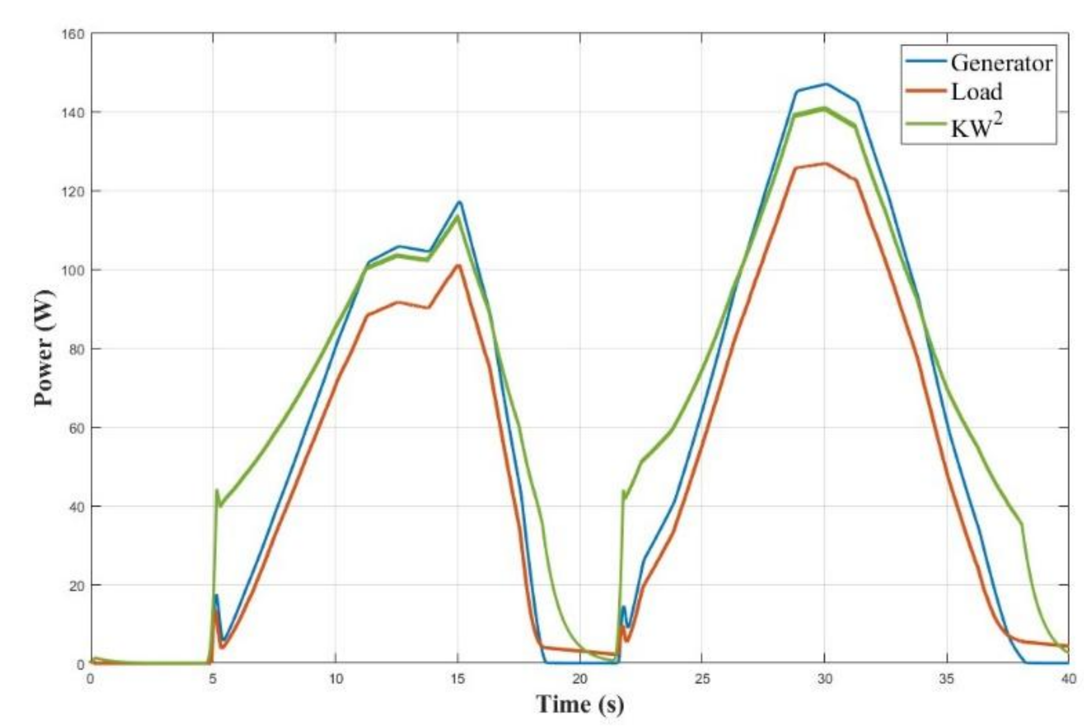
- Perturb and Observe (P&O): The operating point of the system is perturbed by incrementing the input voltage and observing its impact on the subsequent output power.
- Incrementation of the input voltage is often achieved by varying the duty cycle by a constant value.
- The goal of the algorithm is to find the operating point where the time derivative of power is equal to zero indicating the system is operating at maximum power point.
- The algorithm is most often used in photovoltaic systems but appears promising in our tidal application.

4. MATLAB-Simulink Validation

- Realistic tidal velocities (produced from PNNL's Finite Volume Coastal Ocean Model-based Salish Sea model) feed the Simulink model.
- Tidal turbine, gearbox, generator, passive rectifier, and full bridge converter are modeled in MATLAB-Simulink.
- The P&O algorithm is implemented via a MATLAB function that takes source voltage and current as inputs and outputs a duty cycle. The duty cycle is converted to PWM signal and is sent to the full bridge converter to modulate its operation.
- A 60V battery is used as the load.

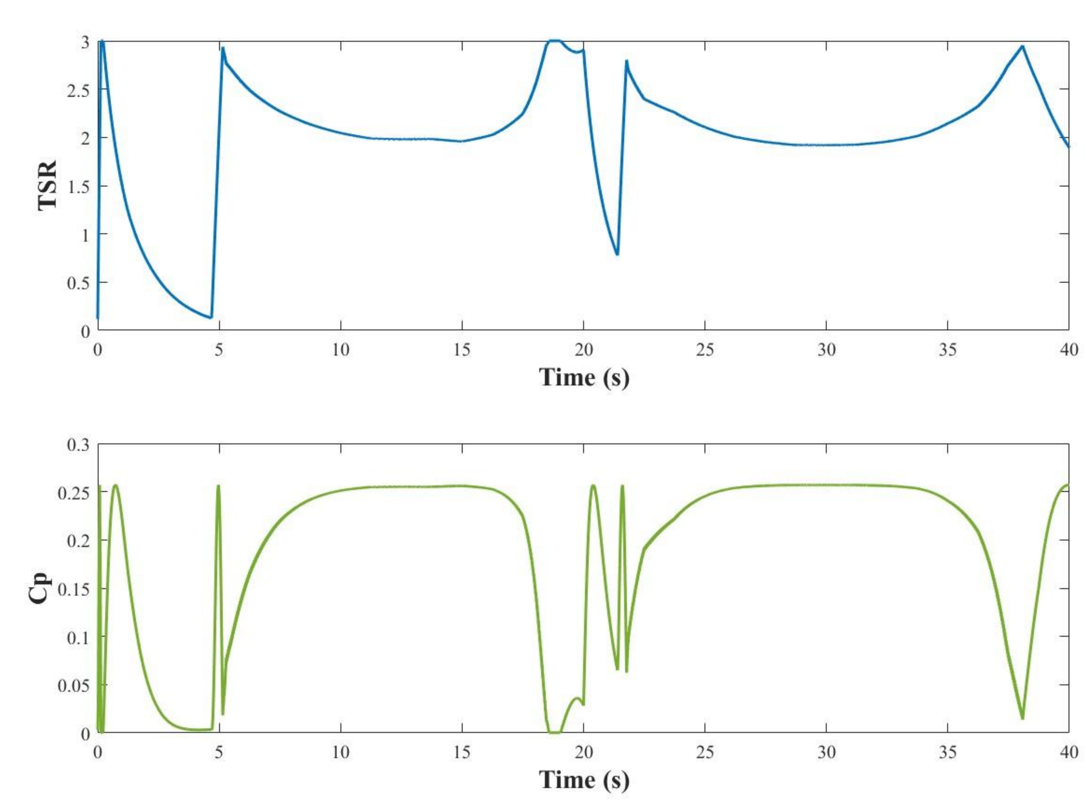

Simulation block diagram

5. RESULTS



Simulated generator power output (Generator), power measured at the load (Load), and theoretical power based on KW^2 torque (KW^2).

- Input tidal velocity data encompasses a full tidal exchange.
- Water velocity begins at 0.5 m/s, which is below turbine cut in (0.6 m/s), and increases.
- Load power closely tracks the estimated MPPT power (KW^2), with a minor expected lag while the turbine spins up.
- Minor losses incurred from electronics inefficiencies are seen between generator and load power.



Simulated turbine tip speed ratio (TSR) and coefficient of performance (Cp) over time

- Control methodology is able to track optimal turbine capacity factor (0.25 maximum for the modeled turbine).
- Relatively smooth spin-up to optimal tip speed ratio of around 2.
- When tidal speed drops below cut in electronics stop pulling power to allow turbine to spin freely.

CONTACT
emma.geon@pnnl.gov
linnea.weicht@pnnl.gov