SAND2022-12973C

RT22
ENERGIZING TOMORROW

Real-Time Modeling of WEC Array Control System on OPAL-RT Platform

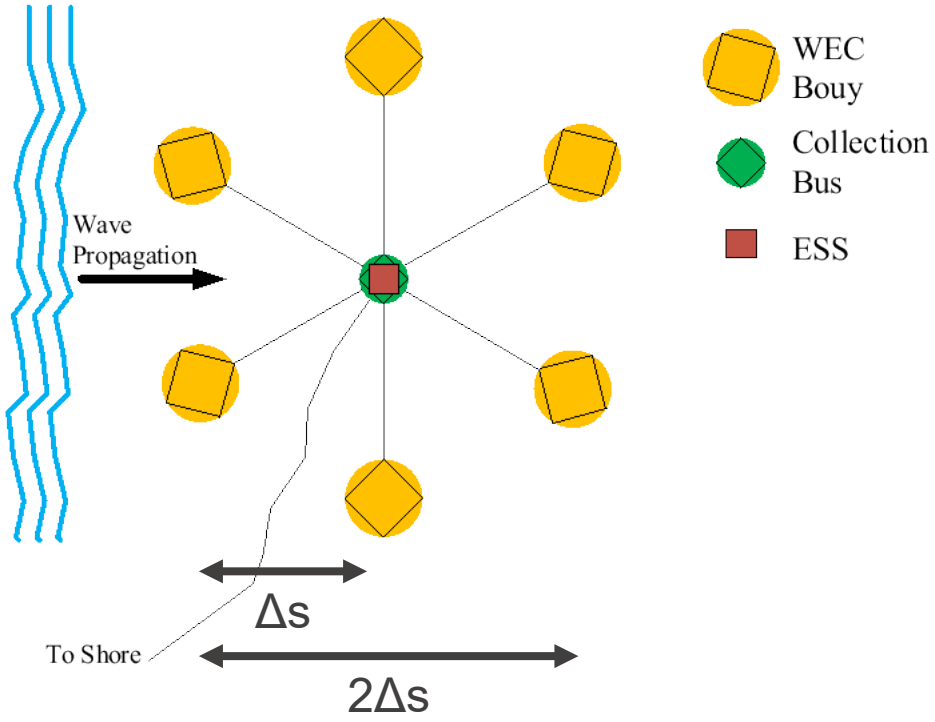
Presenter: Ronald Matthews[1]
R&D S&E Electrical Engineer
Contributors: Madelyn Veurink[1], Wayne Weaver[2], David Wilson[1], and Rush Robinett[2]
1: Sandia National Laboratories
2: Michigan Technological University

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

TECHNICAL GOAL

Take advantage of “electrical phasing” with a buoy array to

- Minimize: Energy storage, Power Electronics, LCOE
- Maximize: Power and Power Quality to the Grid.

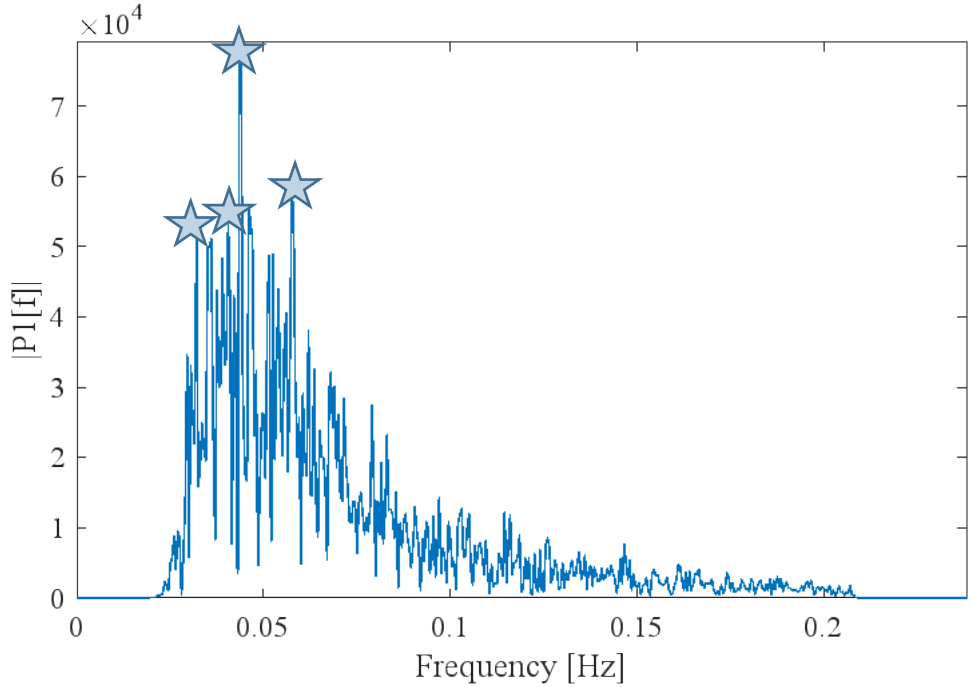


- WEC Buoy
  - The buoy transforms the mechanical energy to electrical energy via a PTO and electric machine.
- Collection Bus
  - A DC bus with a nominal voltage of 325 V.
- Energy Storage System (ESS)
  - Injects a current into the DC bus to regulate the voltage to 325.

RT22 ENERGIZING TOMORROW

WAVE PROFILE

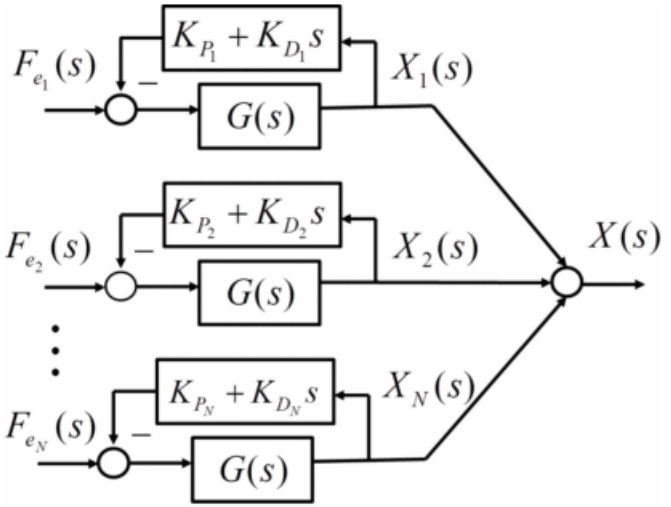
- The wave force is developed from a Bretschneider Spectrum.
  - Generated using the significant wave height and peak period of the wave.
- The wave force was transformed into the frequency domain.



CONTROLLER FREQUENCIES

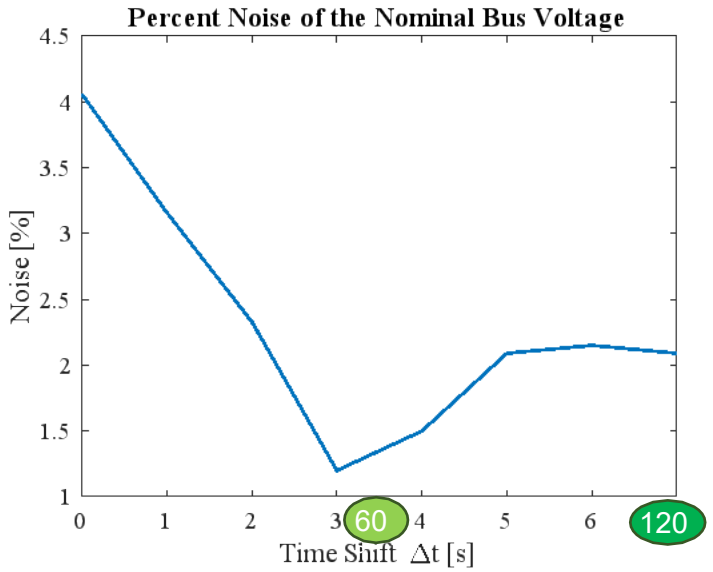
- The top four frequency components in the excitation force were chosen to tune the proportional gain in the controller channels.
- The frequency channels are summed to create the full control force.
  - Increasing the number of channels increases resonance with the wave.

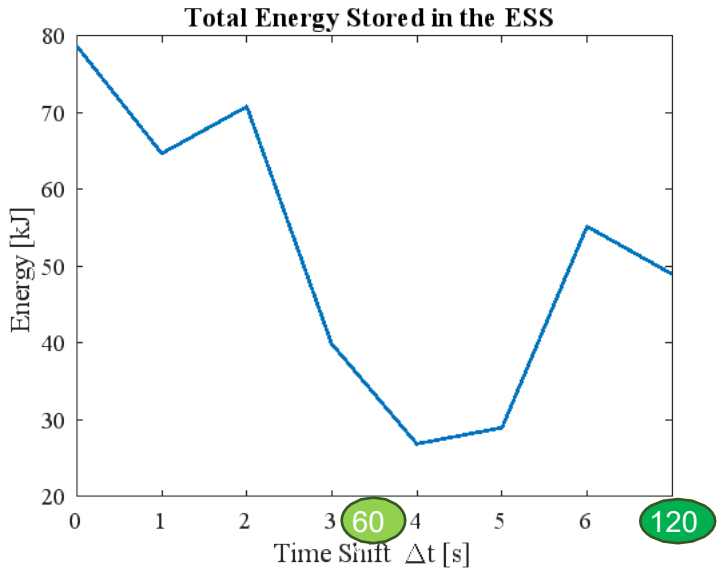
Frequency [Hz] for each of control channels (4)
0.0465
0.039
0.0675
0.0485

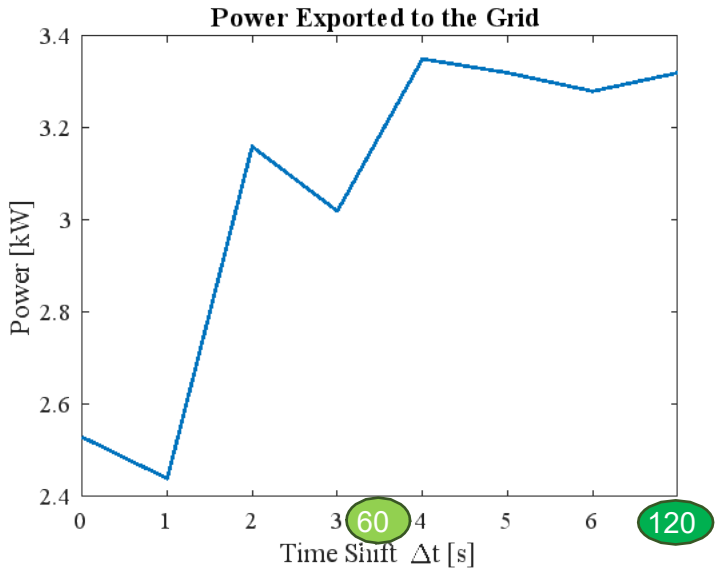


BUS VOLTAGE, MAX ESS POWER, AND GRID POWER FOR TIME SHIFTS

We will see the best outcomes around 60° and 120 ° phase shifts relative to the peak frequency.

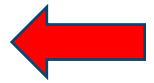






OVERVIEW FOR THE WAVE SPECTRUM

Δs	Degree Shift	Percent Noise [%]	Max Energy [kJ]	Avg. Power [kW]
0		4.06	78.7	2.53
1		3.16	64.7	2.44
2	~30	2.33	70.8	3.16
3	~60	1.2	39.9	3.02
4		1.5	26.9	3.35
5	~120	2.09	29.0	3.32
6		2.15	55.2	3.28
7		2.09	49.0	3.32

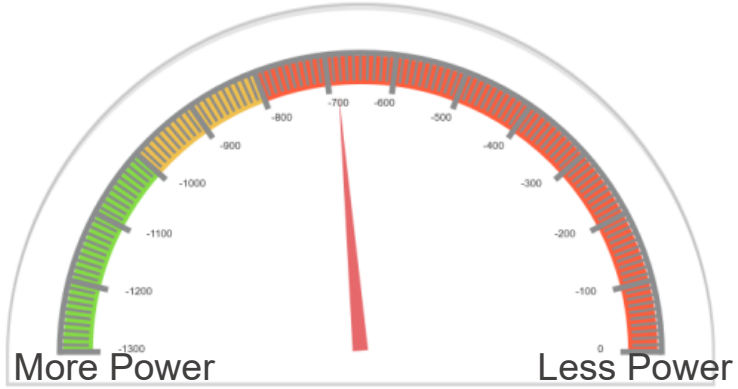


Worst Case

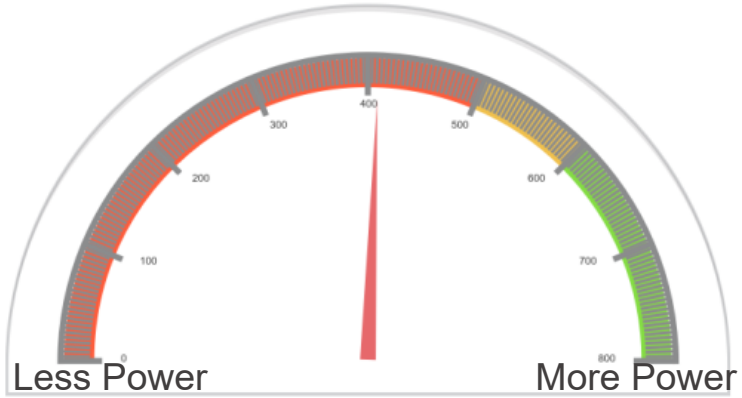
Best Cases

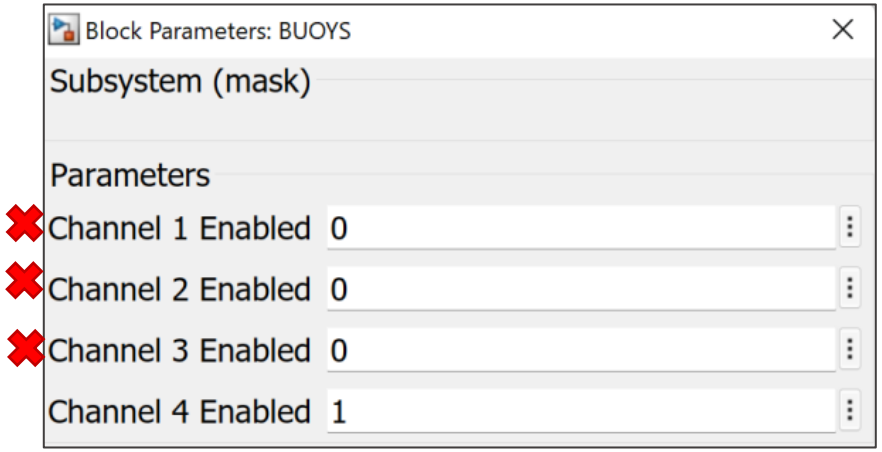
1 CHANNEL CONTROL

PTO Power

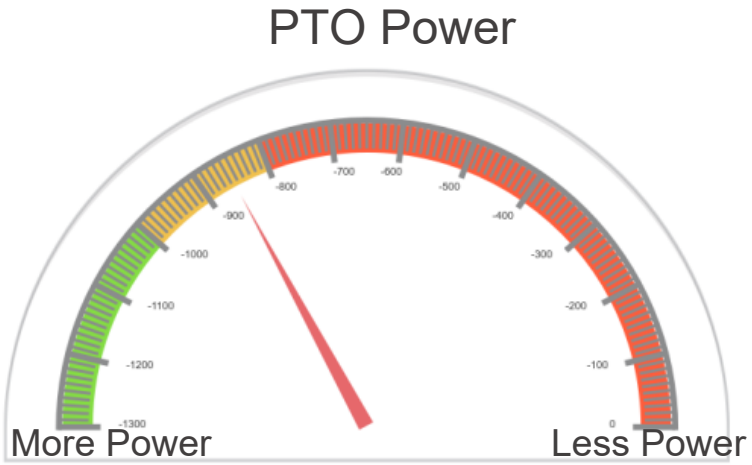


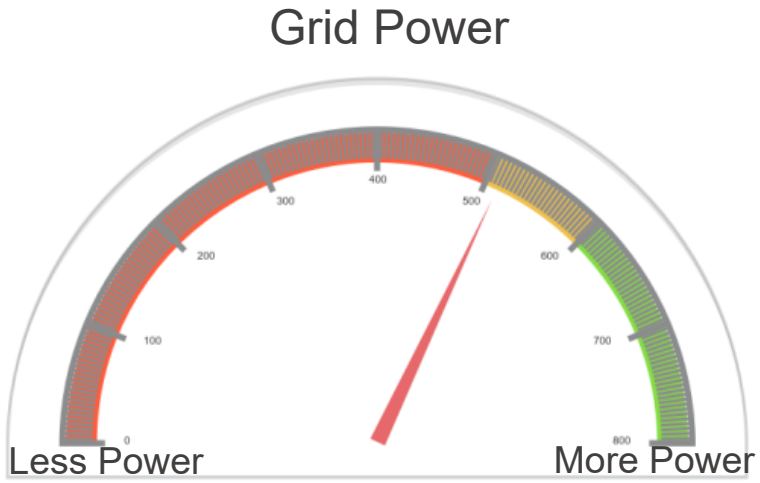
Grid Power

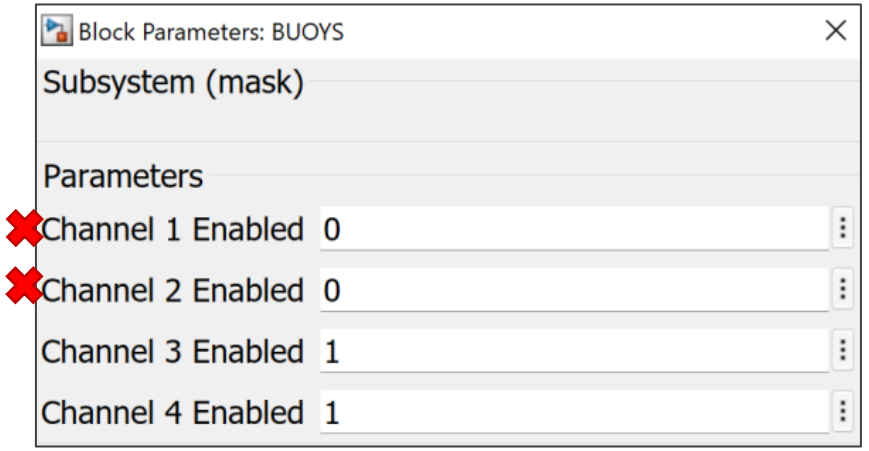




2 CHANNEL CONTROL

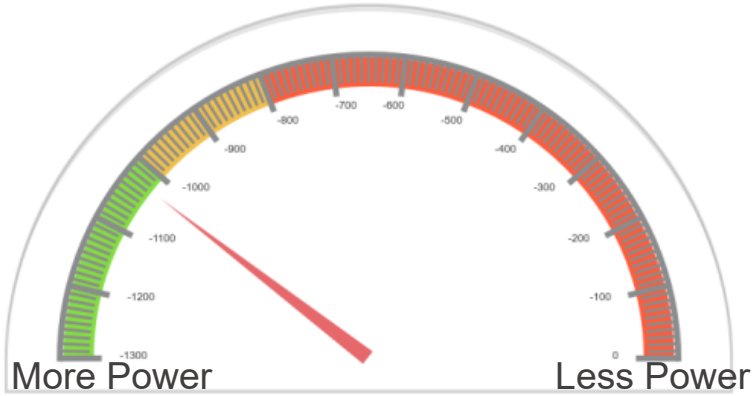




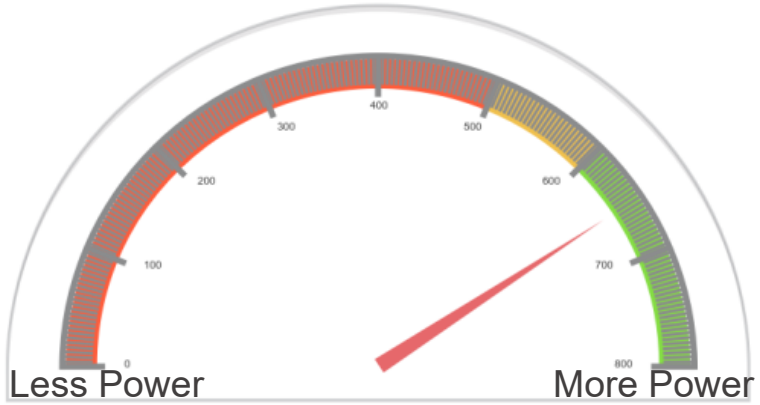


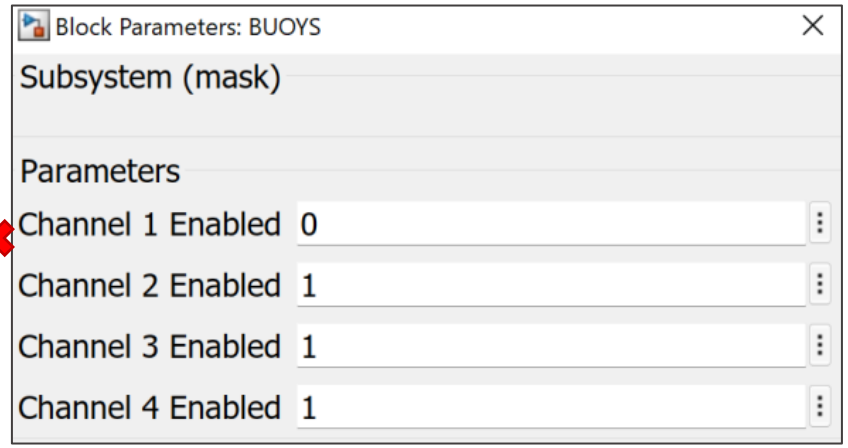
3 CHANNEL CONTROL

PTO Power

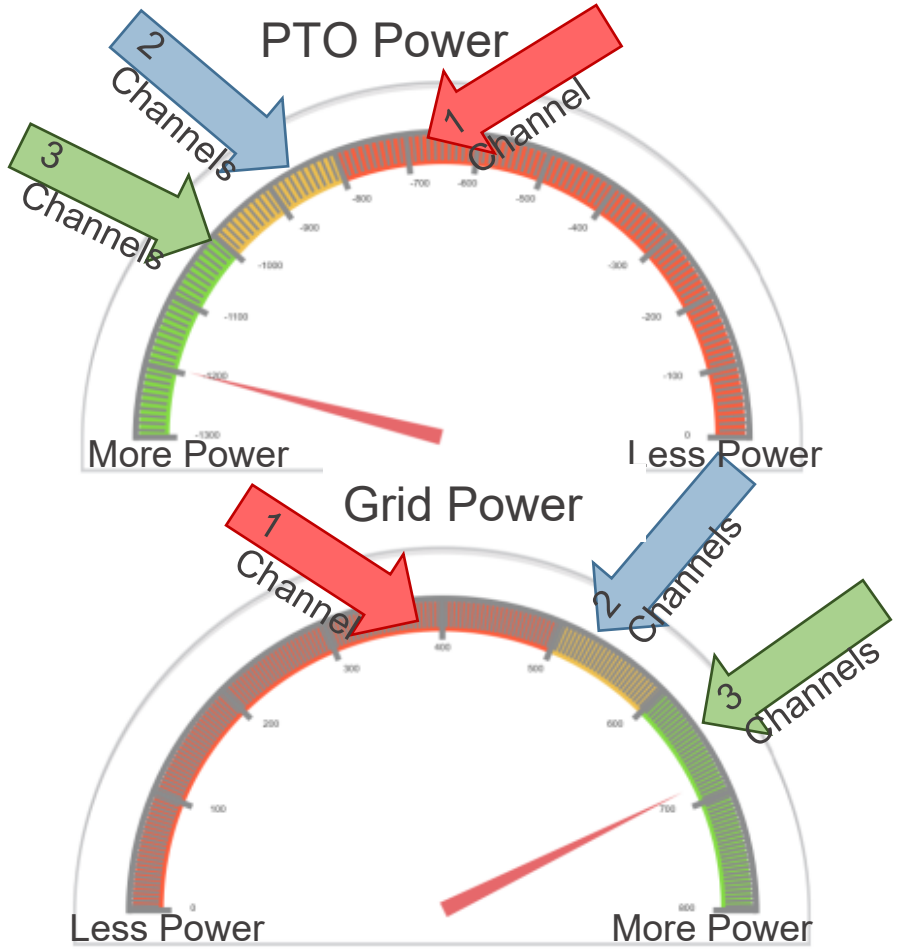


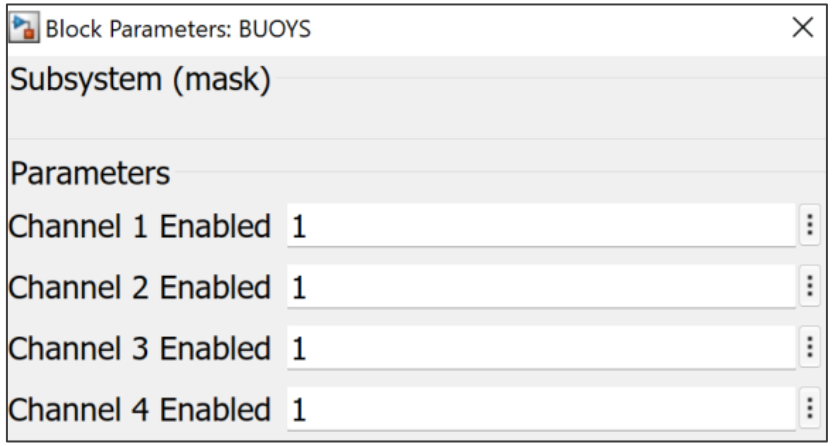
Grid Power



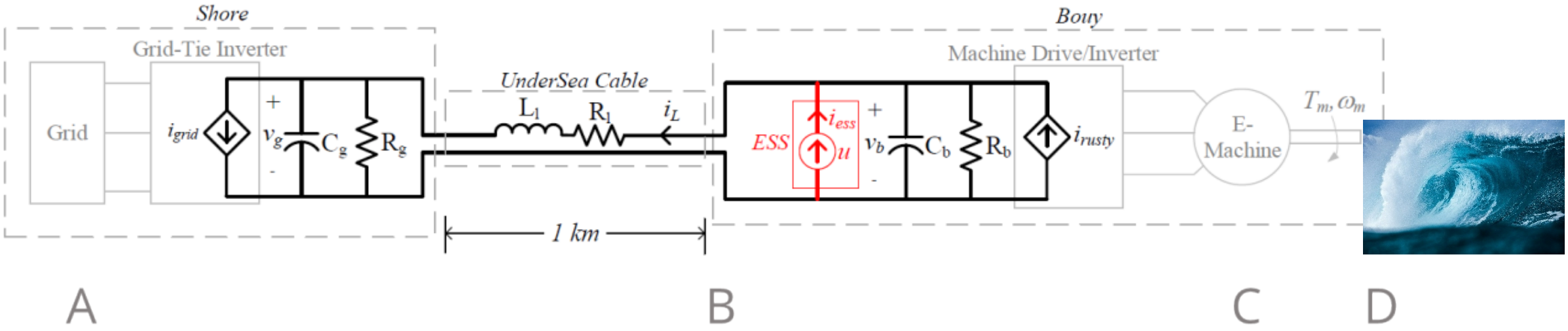


4 CHANNEL CONTROL





REAL-TIME MODEL



$$\eta_{DA} = overall\ efficiency$$

$$\eta_{BA} = PTO\ to\ grid\ efficiency$$

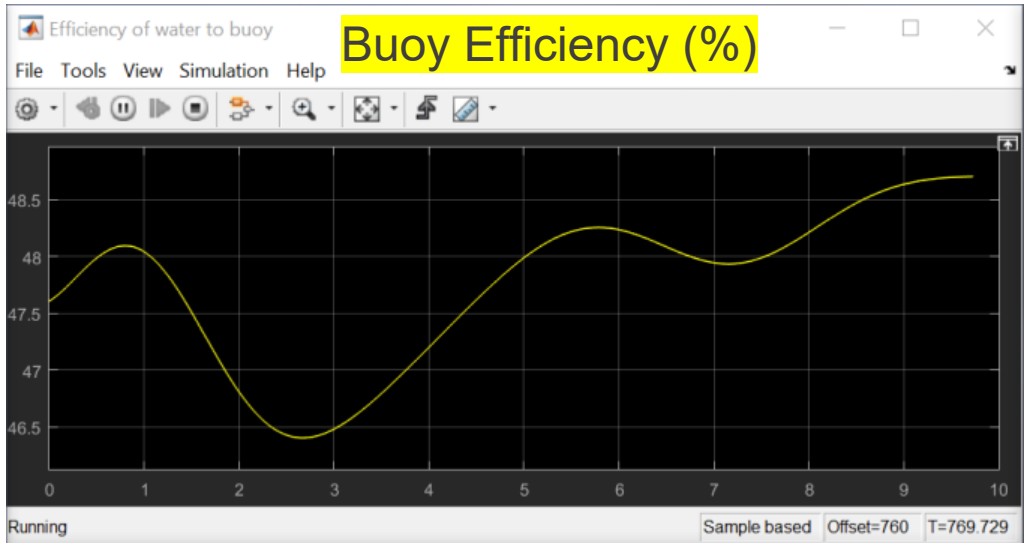
$$\eta_{CB} = PTO\ efficiency$$

$$\eta_{DC} = buoy\ efficiency$$

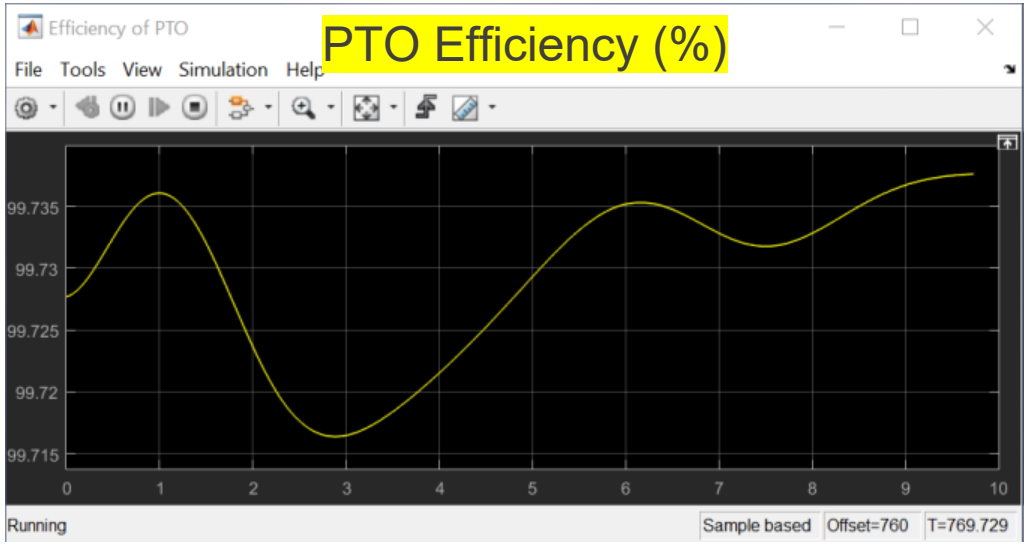
$$\eta_{DA} = \eta_{DC}\eta_{CB}\eta_{BA}$$

REAL-TIME MODEL

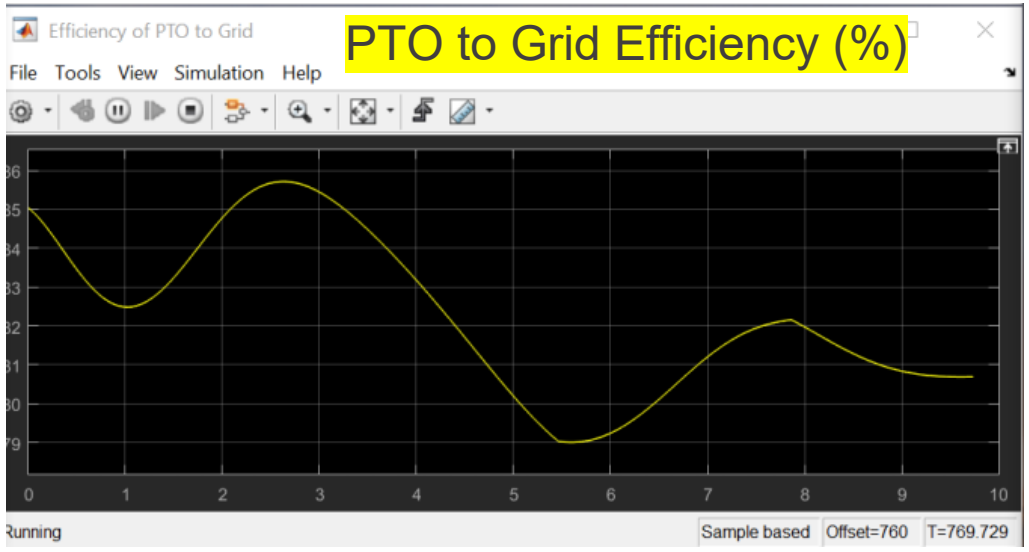
Buoy Efficiency (%)



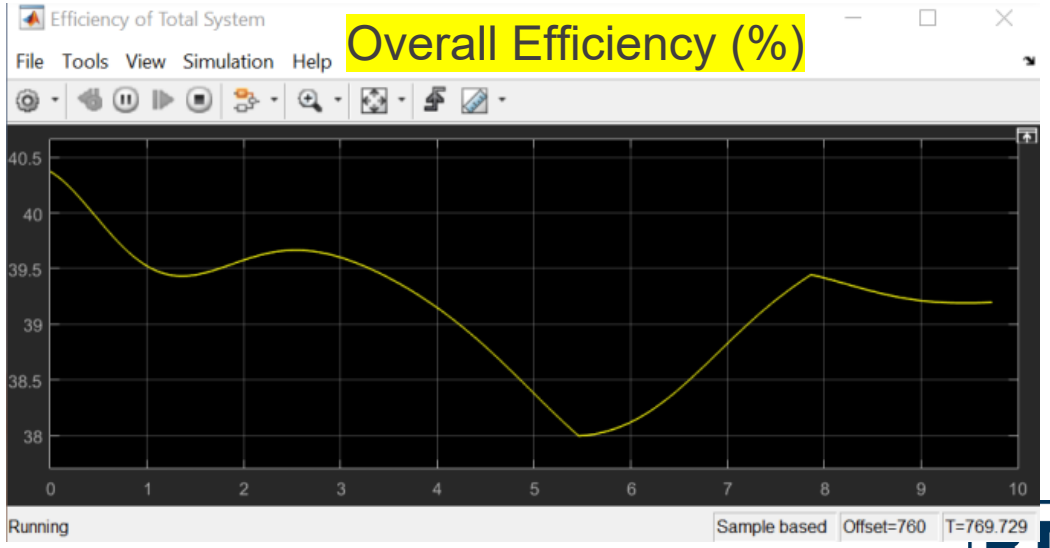
PTO Efficiency (%)



PTO to Grid Efficiency (%)



Overall Efficiency (%)



SUMMARY/CONCLUSION/NEXT STEPS

- Shifting the position of the buoys in the array creates advantageous electrical phasing
  - Minimizes power electronics and energy storage.
  - Maximizes power delivered to the grid.
- The additional frequencies in the spectrum impact the minimum values so they do not show up exactly at 60° and 120°
- Next Steps
  - Wave angle relative to the array.
  - Multi-array phasing.
  - Nonlinear WEC.
  - Additional tuning of PDC3 parameters needed to improve buoy energy conversion efficiency