Integrated Design of Linear Generators

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Work stream 5: Electrical Power Take-Off and Power Conditioning

Introduction

One promising technology for power take-off in Wave Energy Converters (WECs) is direct drive linear electrical machines. The principle is identical to a conventional rotary generator but 'unrolled' into a straight line. Many possible generator topologies exist and the object of this research is to optimise and compare several of these options, such as the generators shown here.

Objectives

- Develop integrated structural and electrical models of the linear generators shown in Figure 1.
- Use these models create an optimisation tool for each generator type.
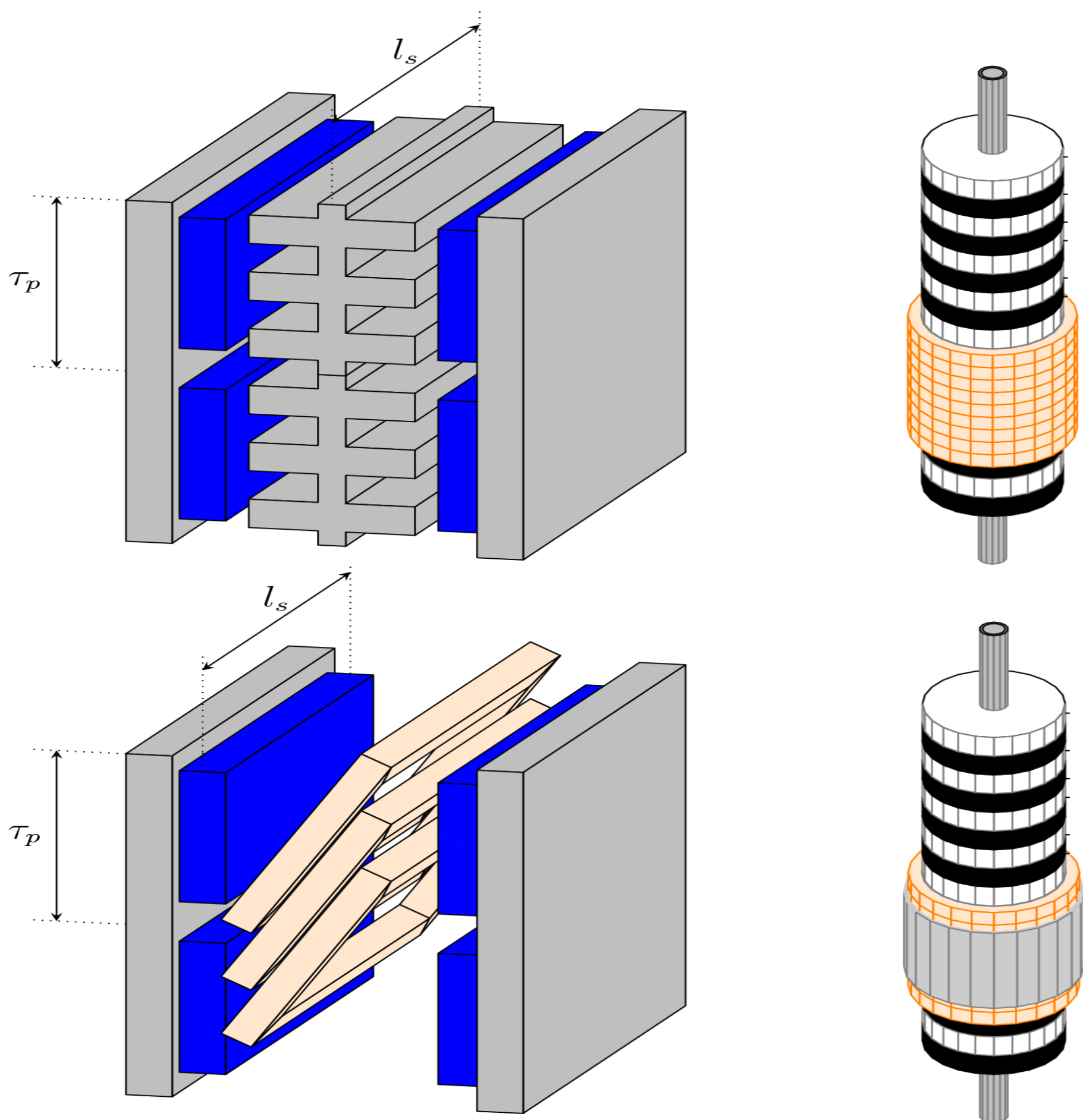- Compare and contrast the generator types under realistic conditions.

Figure 1. Clockwise from top left: The Linear Permanent Magnet Synchronous Machine, The Air-Cored Tubular Machine, The Slotless Tubular Machine, The Air-Cored Permanent Magnet Machine.

Electromagnetic Analysis

The machines are analysed using a combination of classical analytical techniques and finite element analysis. From this, we calculate electrical properties such as predicted voltages etc. and also calculate the internal machine forces.
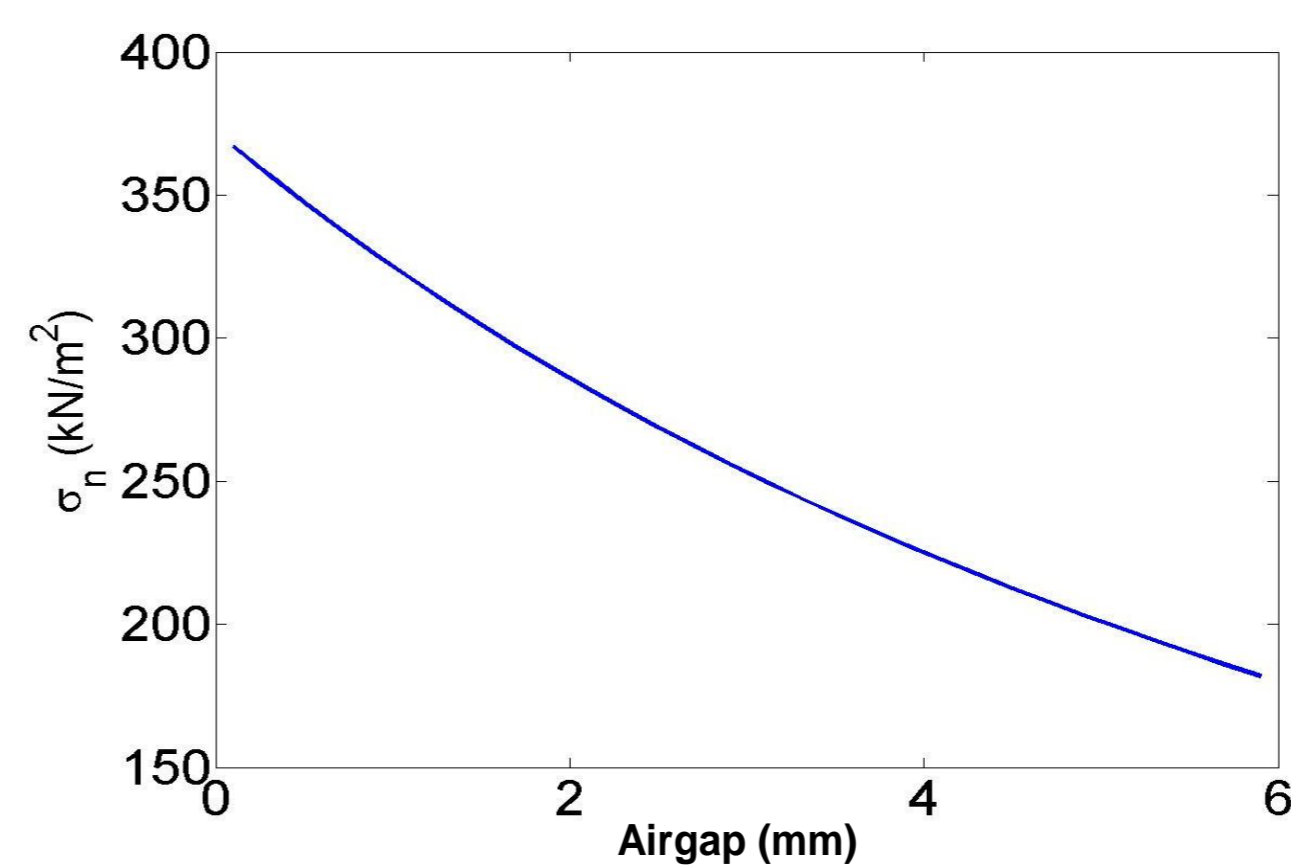

Figure 2. Air-Gap closing stress for the linear permanent magnet synchronous machine for varying air-gap sizes.

Structural Analysis

The large internal forces must be withstood by an appropriate structure. The minimum structure required can be estimated using classical structural analysis, such as beam theory, and FEA models.
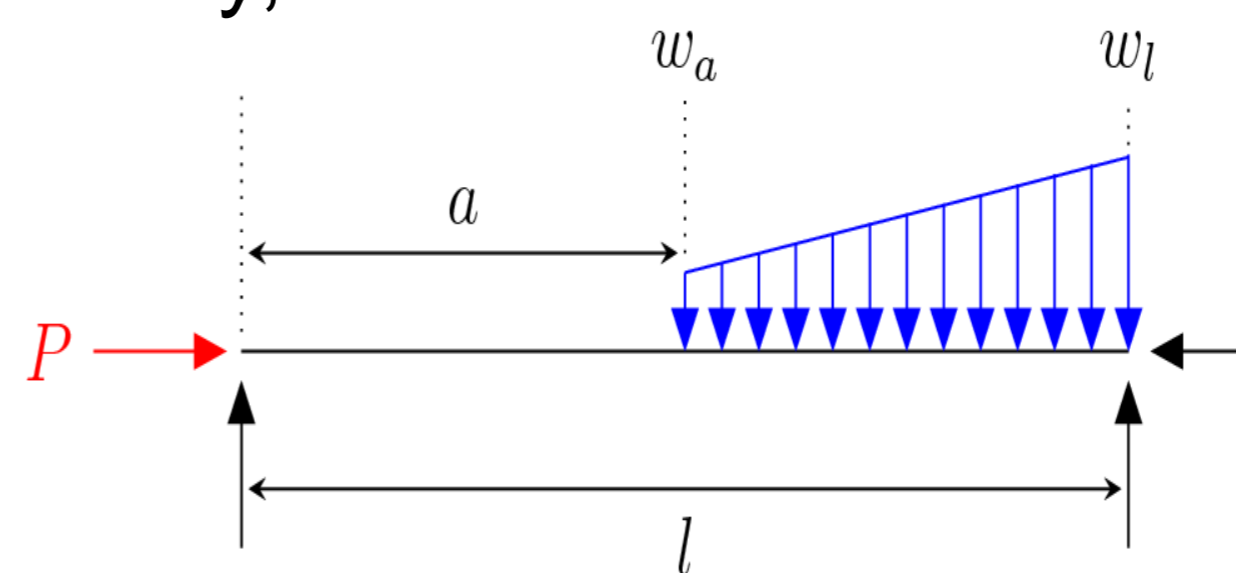

Figure 3. A typical structural loading case for the tubular machines, multiple cases are superimposed.

Hydrodynamic Simulation

Using a published model, the machine is simulated in realistic wave conditions as part of a heaving buoy WEC.

Optimisation

When the models are fully integrated, they can easily be optimised using a genetic algorithm,. Suitable genetic algorithms have been identified and tested. Appropriate scoring mechanisms have also been investigated based on the cost of energy produced, and other penalty factors.