# Robust Power Transmission Solutions

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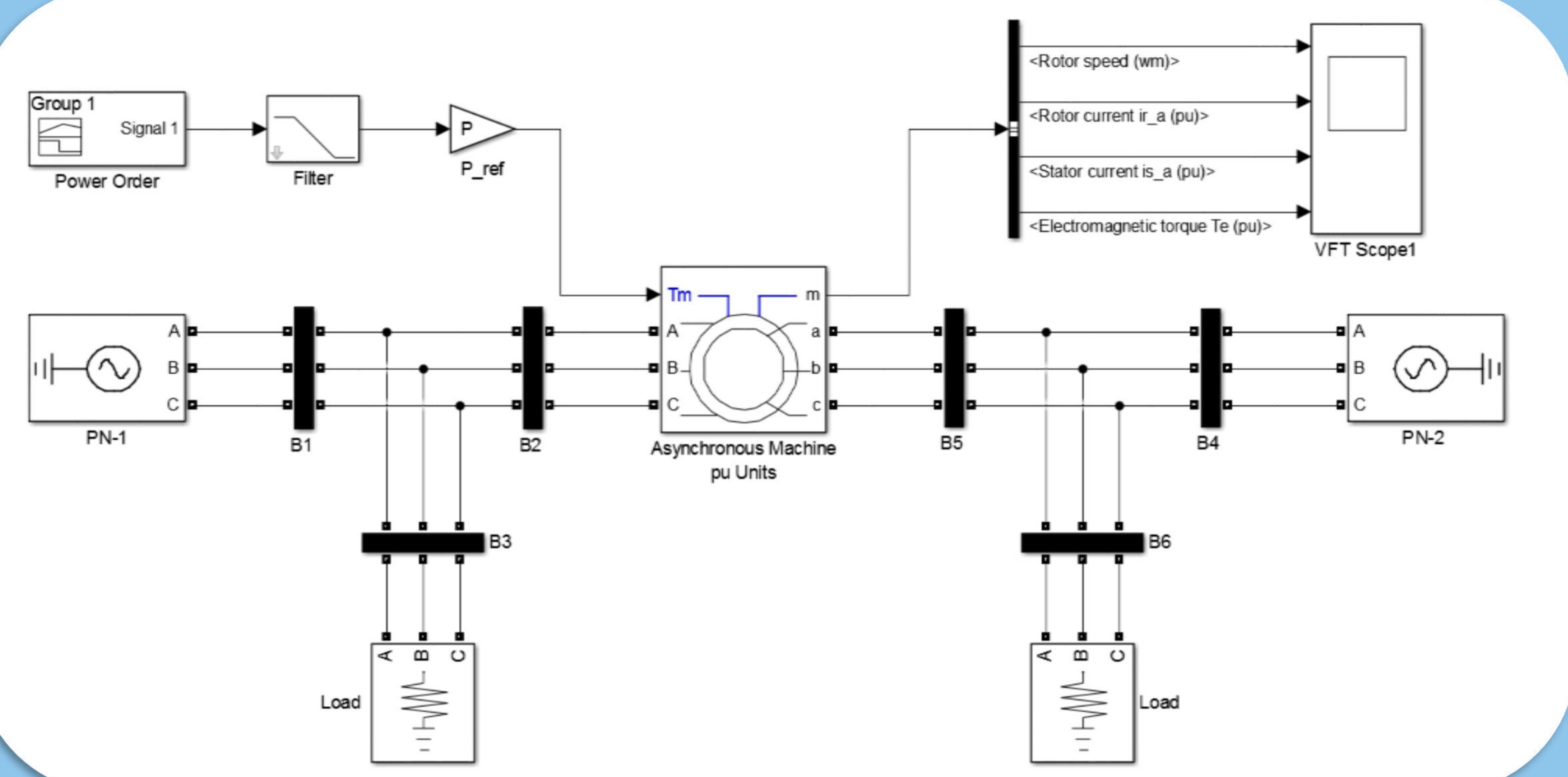
## Background

The continuous phase shifting transformer is a wound rotor induction machine (WRIM) repurposed for the transferal of power between networks. Similar to a doubly fed induction generator (DFIG) in design, it allows the interconnection of two asynchronous grids.
This is a case study on an existing installation to help better understand the operation and mathematical modelling of the transformer.

## Motivation

With the growing capabilities of control engineering it is thought that this modified transformer could serve as a reliable and robust alternative to costly converter stations to connect between asynchronous networks.
There are currently only a small number of these machines in operation around the world, with notable examples installed at Hydro-Quebec, Canada; Laredo, Texas and Linden, New Jersey.



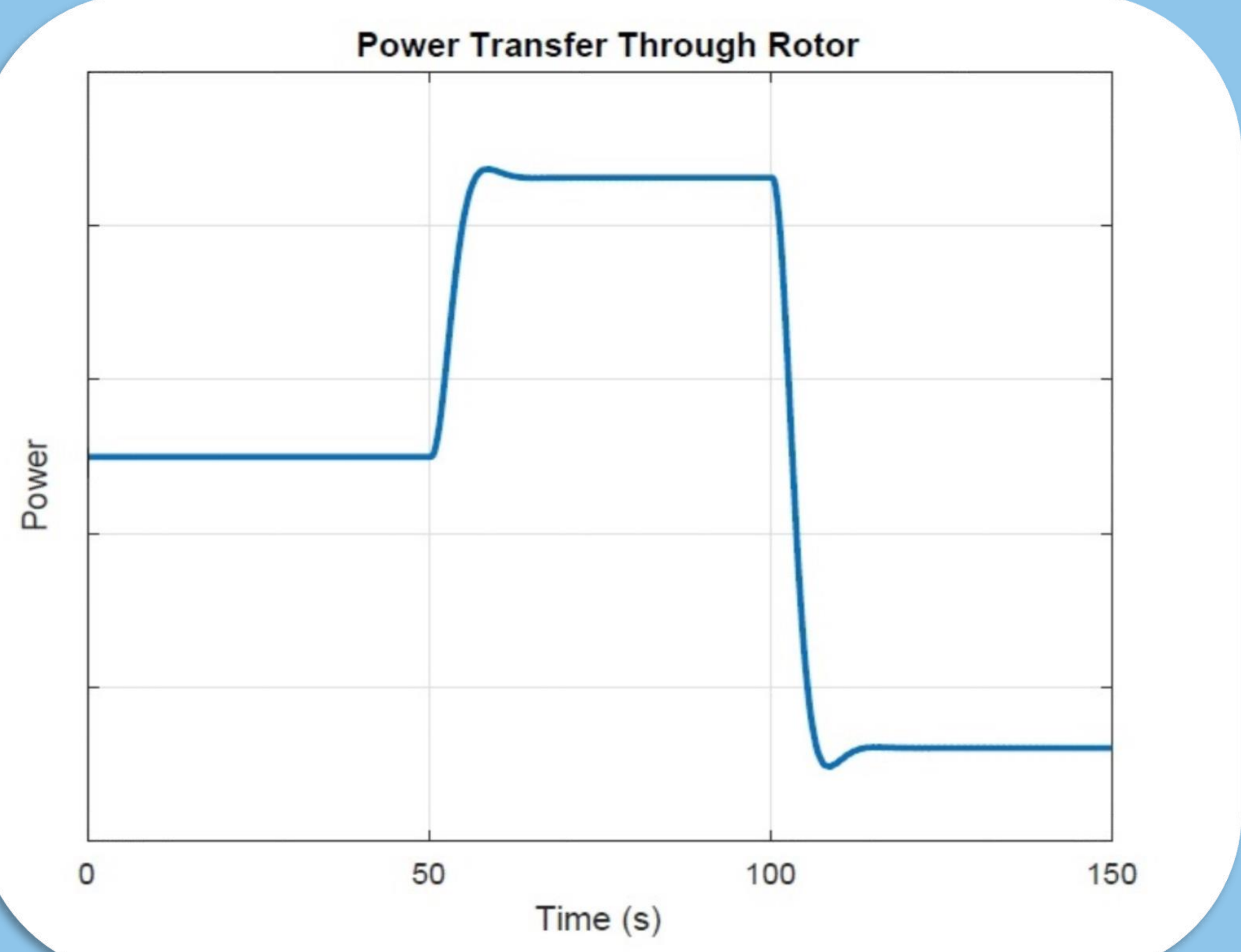




Figure 1 (top):
Model of the machine implemented in Simulink

Figure 2 (centre):
Power flow response to a step change of ± 1pu

Figure 3 (bottom):
Reactive power consumption at varying amounts of grid asynchronicity

## Model

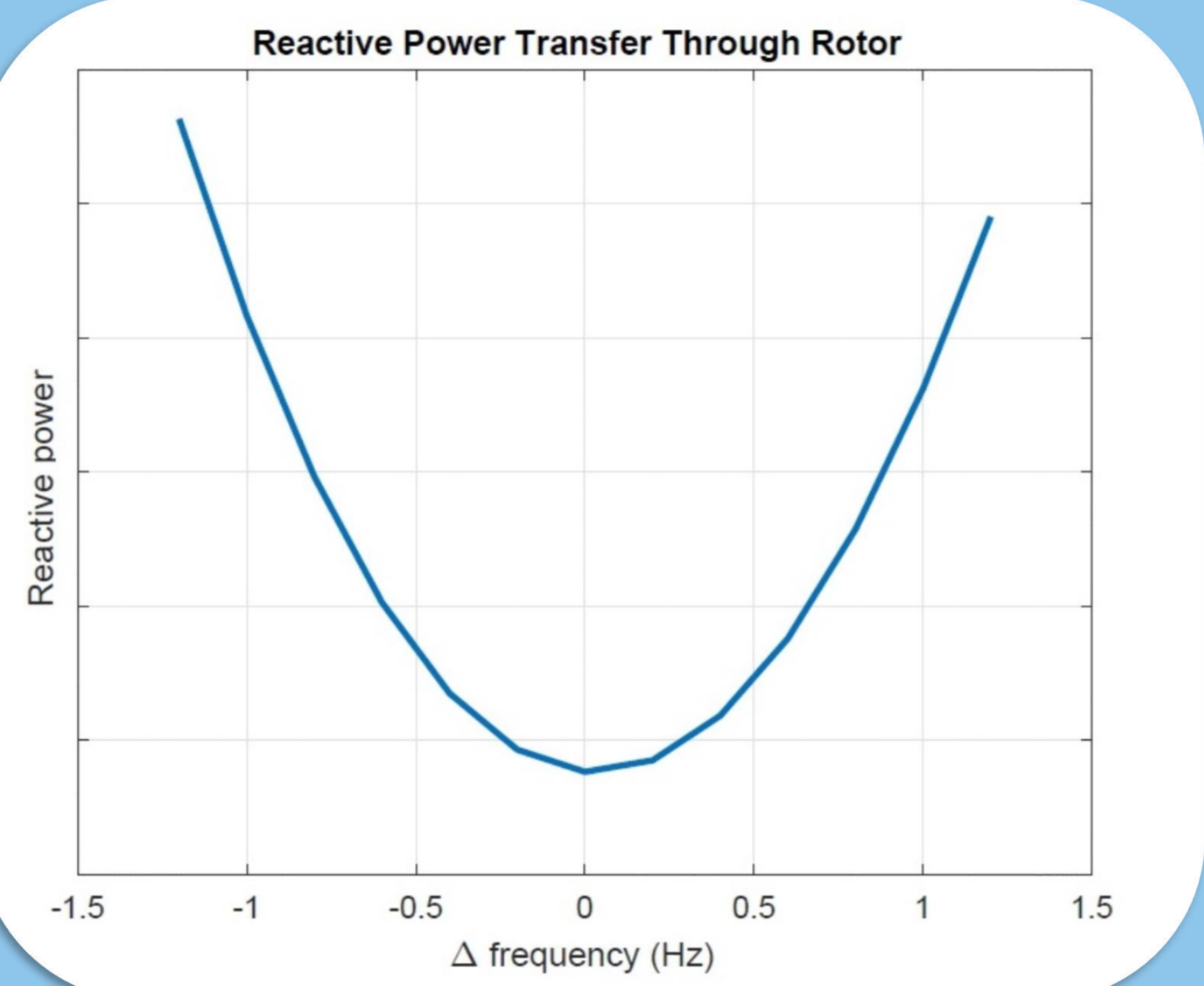
The continuous phase shifting transformer has been modelled as an asynchronous machine with power network 1 (PN-1) connected to the stator windings and power network 2 (PN-2) connected to the rotor windings, as shown in figure 1.

In this simulation, a torque was applied to the machine to simulate a power transfer of 1pu followed by an order -1pu to demonstrate the capability of bi-directional power flow between synchronous networks. Figure 2 shows the results. Torque applied in one direction causes a flow of power from PN-1 to PN-2, while a change in sign reverses the direction of flow due to the proportionality of power and torque.

A second simulation was conducted to model the interconnection of asynchronous networks by varying the electrical frequency of PN-2. When two networks of different frequencies are connected through the WRIM, the natural response of the machine is to rotate at a speed proportional to the phase difference. This energisation comes at the expense of reactive power.

Figure 3 shows that the synchronous reactive power consumption at $\Delta f = 0$ rises sharply as the difference in frequency increases.

With this model, the maximum difference in frequency between networks is currently around ±2Hz. Beyond this point, the stator and rotor magnetic fields lose synchronism, resulting in machine failure. While this tolerance to a difference in frequency may seem low, this is an ideal range to deal with fluctuations between neighbouring grids.




## Conclusions

The continuous phase shifting transformer has demonstrated its ability to be incorporated into the existing transmission network. Unlike a traditional phase shifting transformer, the continuous, smooth operation eliminates harmonics that would otherwise be present with a discrete tap-changer, producing a much better quality of power.

The continuous phase shifting transformer aids in system stability via its large inertia and also by providing an alternative short circuit path in the event of a fault. While a power electronic converter may fail at a fault a little over 1pu, the VFT is capable of withstanding many more multiples of this.

Future work will focus on the reactive power requirements of the machine. It is understood that switching capacitor banks may be connected to either side, or alternatively the installation of a static VAR compensator (STATCOM) may help to reduce the curve in figure 3 to an ideal straight line.

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