Aalto University
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# Distributed Generation Technologies

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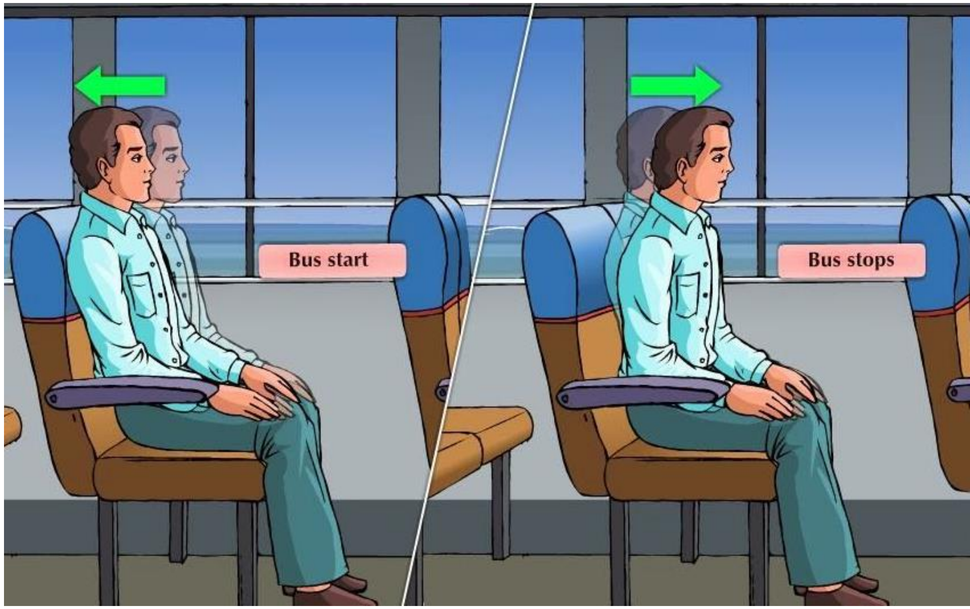
# Chapter5:
# Operation and Control of Converter-Based Synchronous Generators

## The Main Objectives of this Session:

At the end of this session students will be able to answer the following questions:

1. **What is inertia?**
2. **What is the role of inertia in power systems?**
3. **How can we emulate behavior of synchronous generators in a grid-connected DC/AC converter?**
4. **How can we provide required inertia for the power grid by grid-connected converters?**

## What is inertia?



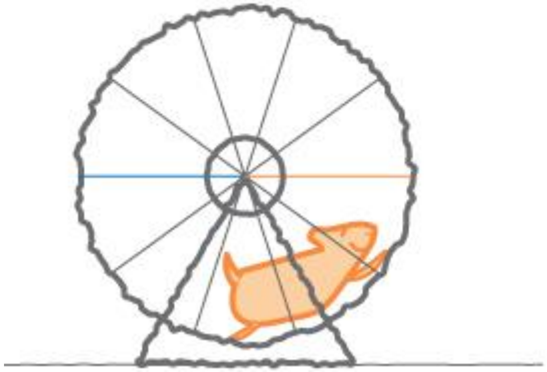

While travelling on a bus, we can notice that the bus starts suddenly, we tend to fall backward, and when the bus stops suddenly, we tend to fall forward.

There is a reason why this happens. It's due to **Inertia**.

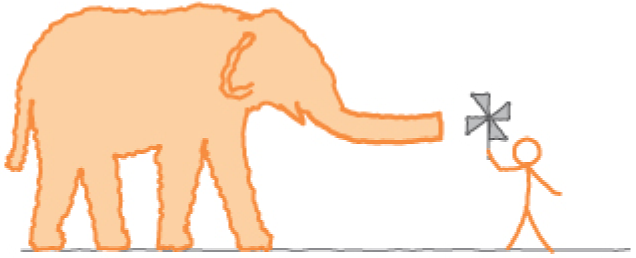
**Inertia** refers to the **resistance to any change** in state of **motion** or **rest** or **direction**.

That Means a body in **rest** wants to **stay** in **rest** and a body in **motion** wants to **continue moving**.

What happens if a hamster on a wheel suddenly **stops running**?



What happens when elephant **stops blowing air** on **Pinwheel**?



## What Is Inertia in the Power Grid?

Inertia in power systems refers to the energy stored in large rotating generators and some industrial motors, which gives them the tendency to remain rotating.

**Inertia** is the main reason which today's grid is so reliable, which basically helps the whole system keep running when a power plant fails.

**Supply of power=demand for electricity**



**Governors** detects changes in frequency. measure how fast the generators are spinning and tell power plants to speed up or slow down.

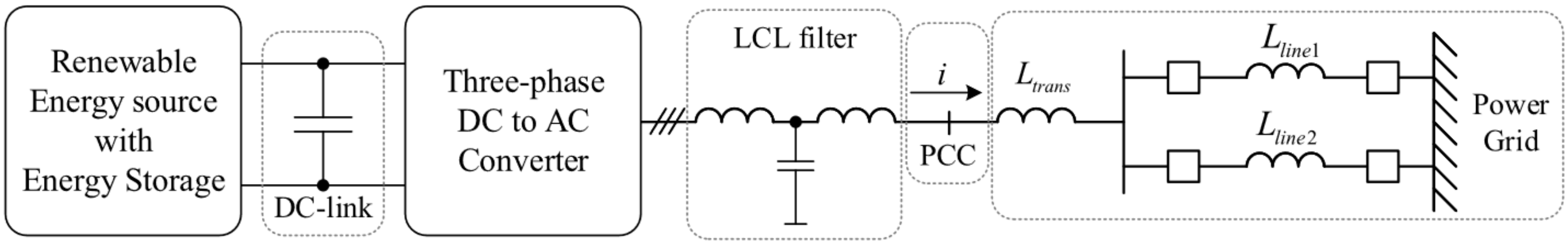
This is essentially the "**cruise control**" for the power grid.

This process **takes time**—**up to several seconds**—for all these levers and valves to work and the power plant to increase output.

That's where **inertia comes in**. It gives the **system time** for all these mechanical systems to react to an emergency—while keeping the **lights on**.

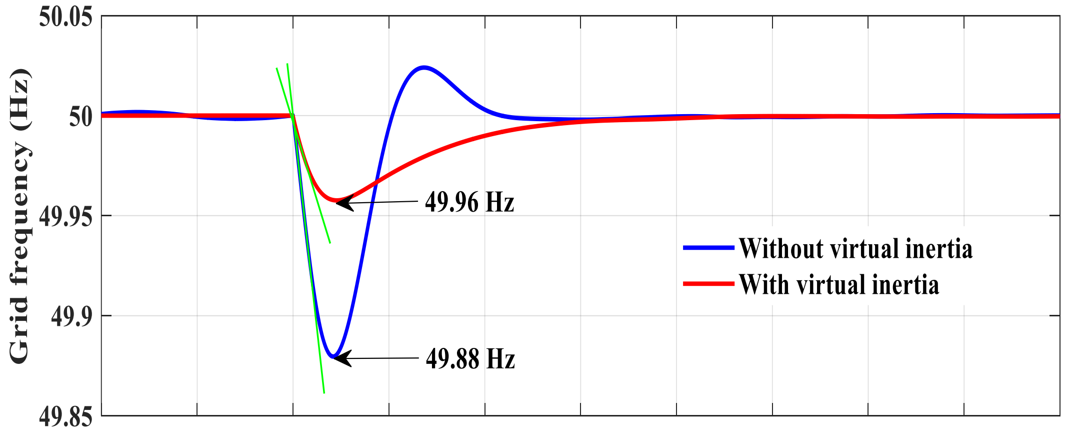
## How we operate when grid is changing toward renewable energies?

The grid is growing to include higher levels of renewable energies (e.g., wind and solar) generation using power electronics converters—which do not provide inertia, due to the lack of rotating mass.




## What are the consequences of decreasing inertia?

When inertia decreases, sudden changes in frequency caused by a change in loads or generation are faster and larger. This means that it is more difficult to keep the frequency within its normal range of variation.




**RoCoF (rate of change of frequency) relays** are widely used for protection. These relays are designed to open the circuit when the system RoCoF reaches a given limit.

Should we all **panic**? NO, because inertia can be provided by implementing the Synchronous generator mimicking concept to control the interfaced converters between renewable energy sources and power grids.

## Emulation of Virtual Inertia in Control Loop of the Interfaced Converters

The virtual inertia emulation control strategy includes the famous swing equation which can approximate frequency deviations of the system based on active power variations.

$$P_{in} - P_{out} = J\omega \frac{d\omega}{dt} + D\left(\omega - \omega_0\right) \tag{1}$$

$P_{in}$: input power of converter provided by energy source in DC side

$P_{out}$: output active power of converter injected to the power grid or load

$J$: virtual inertia

$D$: damping factor

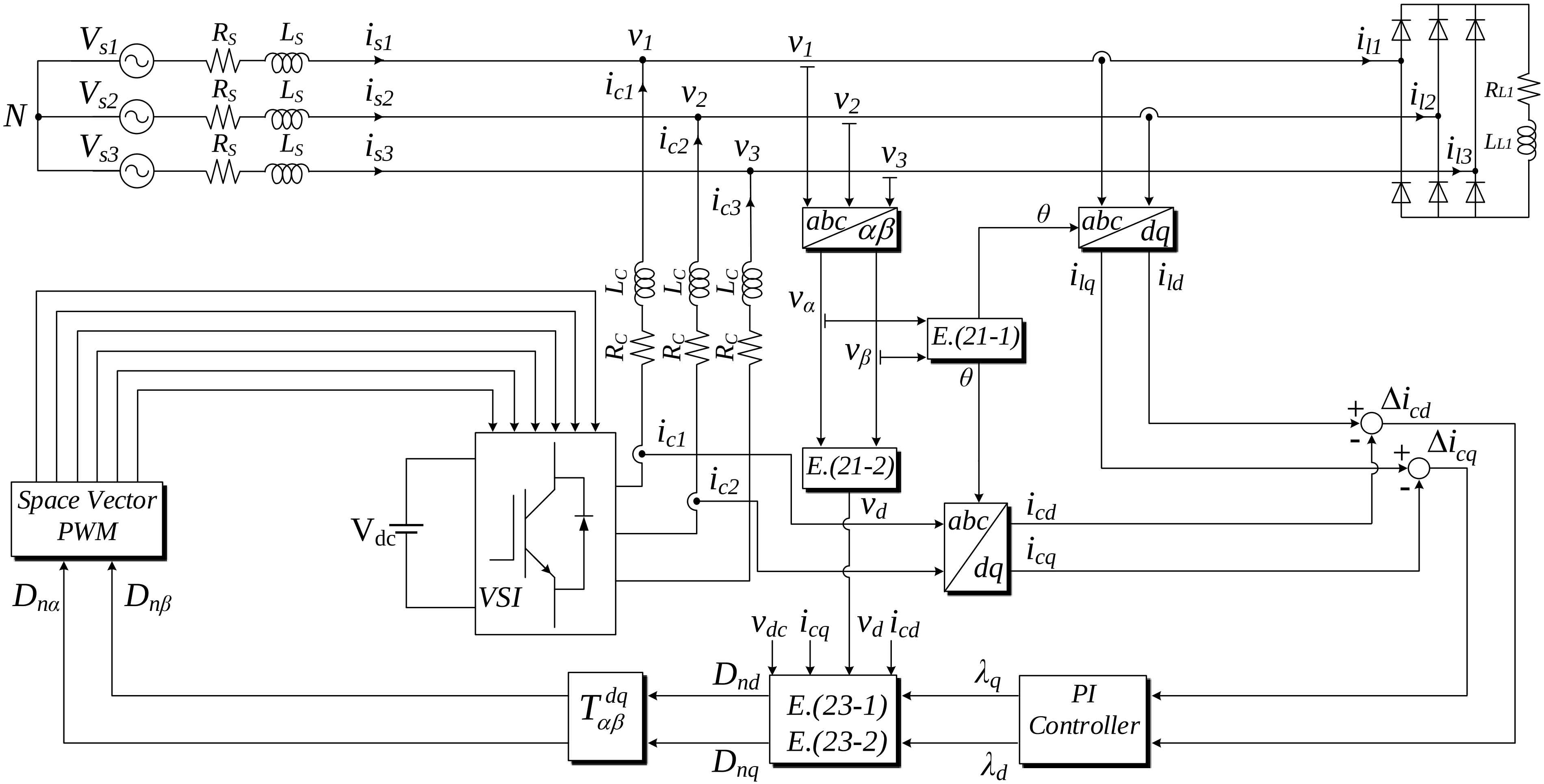
$\omega$: virtual value of the angular frequency

$\omega_0$: reference values of the angular frequency

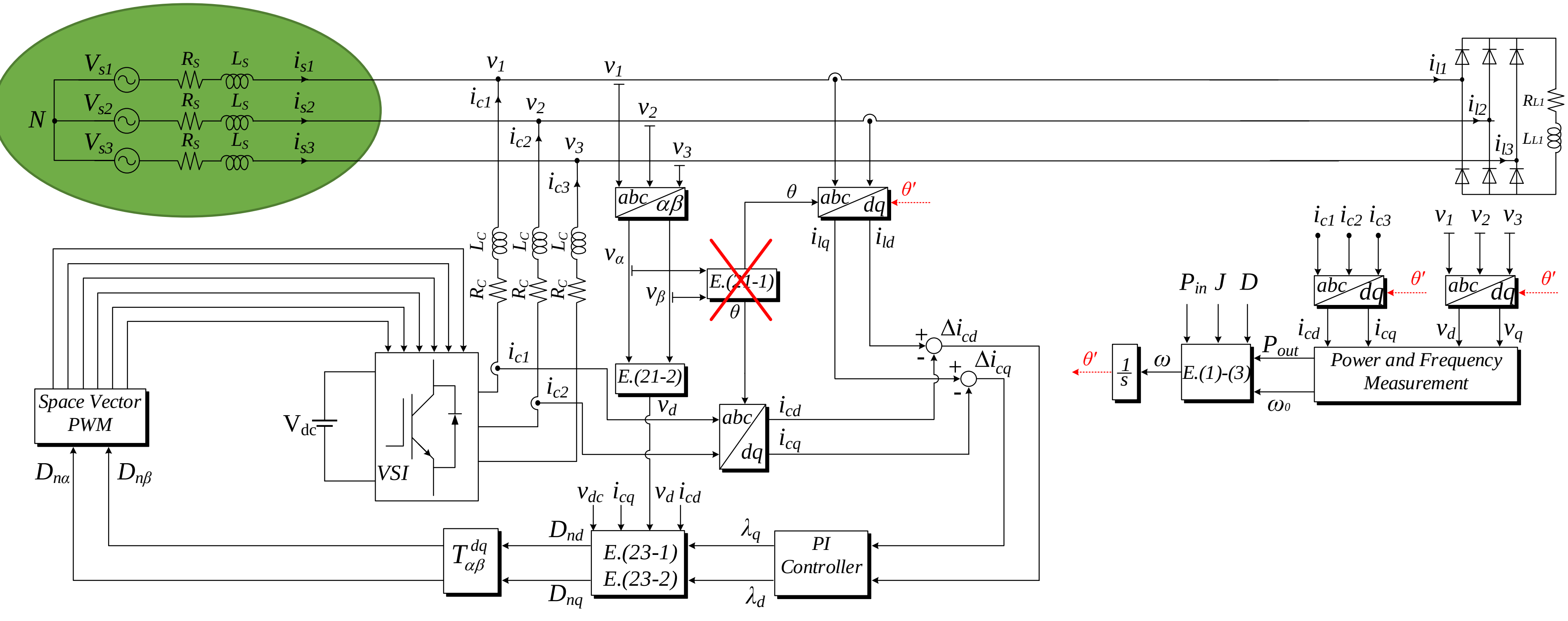
$$P_{in} - P_{out} - D\left(\omega - \omega_0\right) = J\omega \frac{d\omega}{dt} \longrightarrow \frac{d\omega}{dt} = \frac{P_{in} - P_{out} - D\left(\omega - \omega_0\right)}{J\omega} \tag{2}$$

$$\omega = \frac{d\theta}{dt} \rightarrow \theta = \int \omega dt \tag{3}$$

## General schematic diagram



# Emulation of Virtual Inertia in Control Loop of the Interfaced Converters



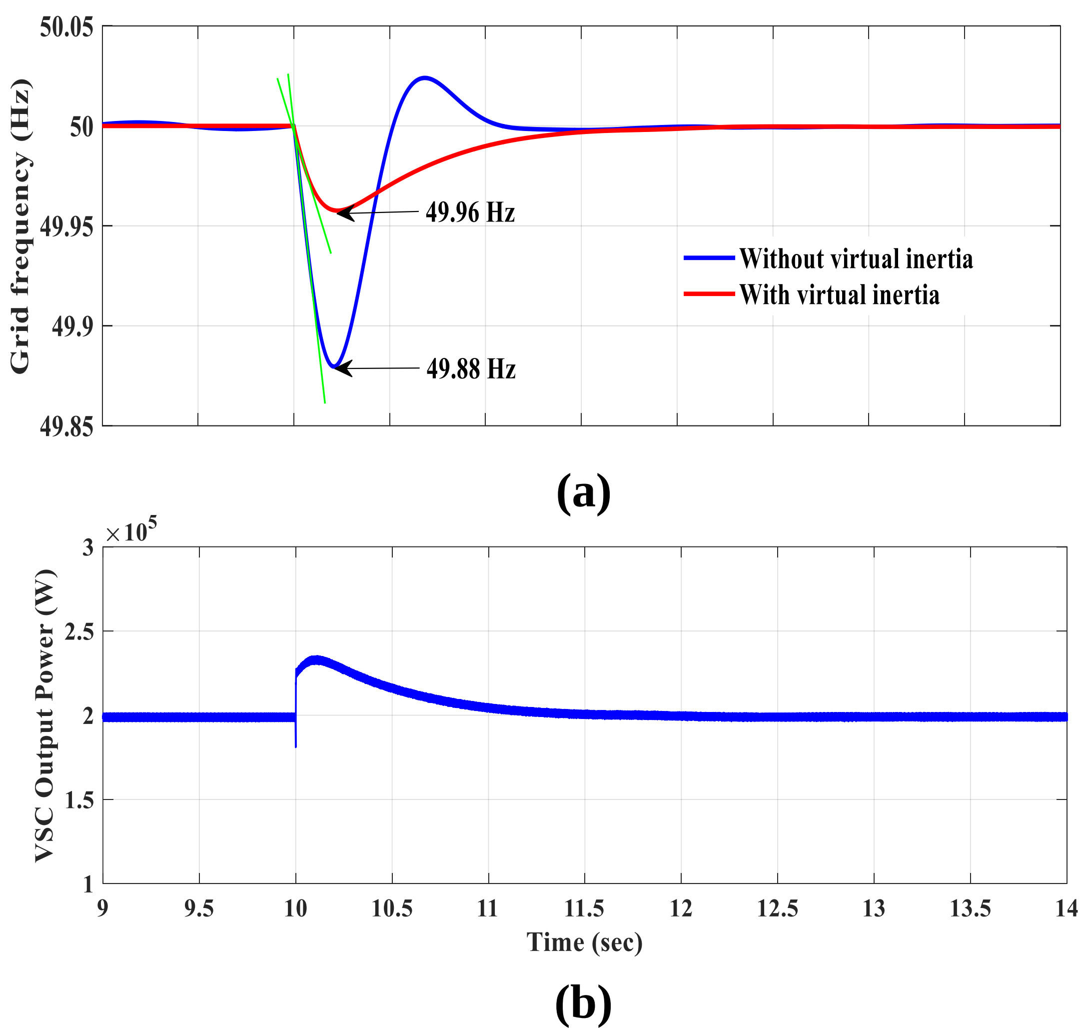



**Fig. 2. (a) Grid frequency and (b) VSC output power curves under step-up change in the demand.**

**Questions and comments are most welcome!**