Aalto University
School of Engineering

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

The most challenging issue with the high-level penetration of RESs to the grid is lack of inertia, which gives rise to the excessive rate of change of frequency (RoCoF) and maximum frequency deviation in respect of reference value (i.e., frequency nadir), as illustrated in Fig. 1.

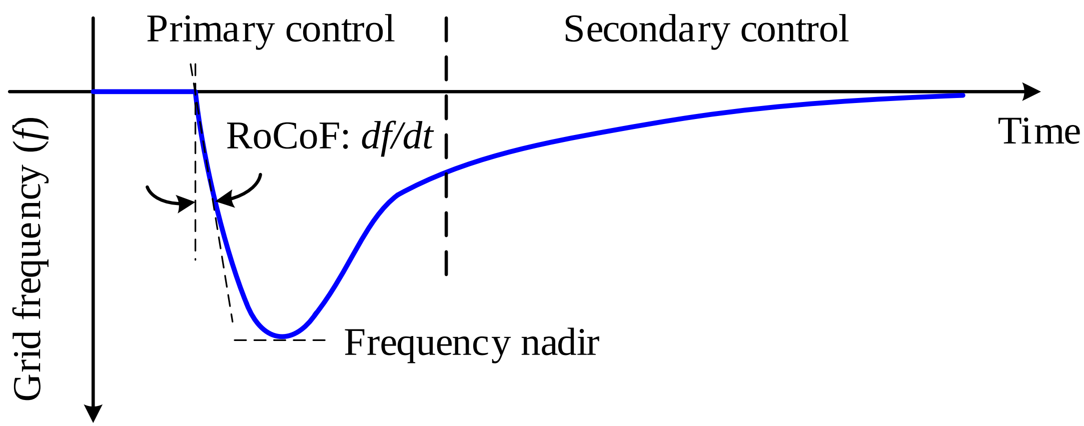


Fig. 1. Change of frequency following a step-up change in the demand.

To mitigate the RoCoF level and improve frequency stability, the idea of providing additional inertia by means of virtual synchronous generator (VSG) can be implemented. This concept is based on emulating dynamic characteristics of real SGs by power-electronic based generators. In other words, frequency regulation and restoration is obtained by grid-tied VSC active power control.

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.

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

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

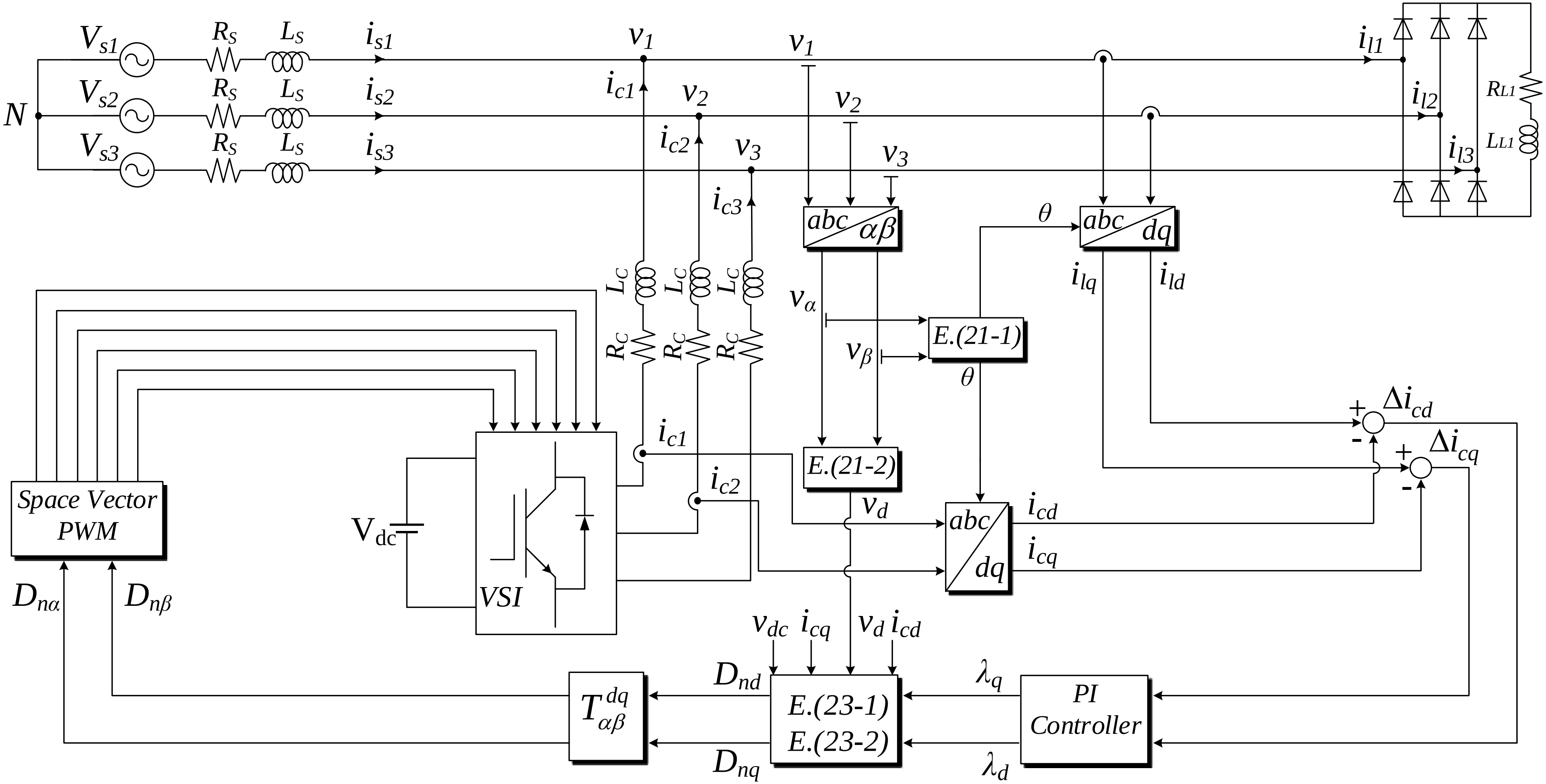
ω: virtual value of the angular frequency

ω_0: reference values of the angular frequency

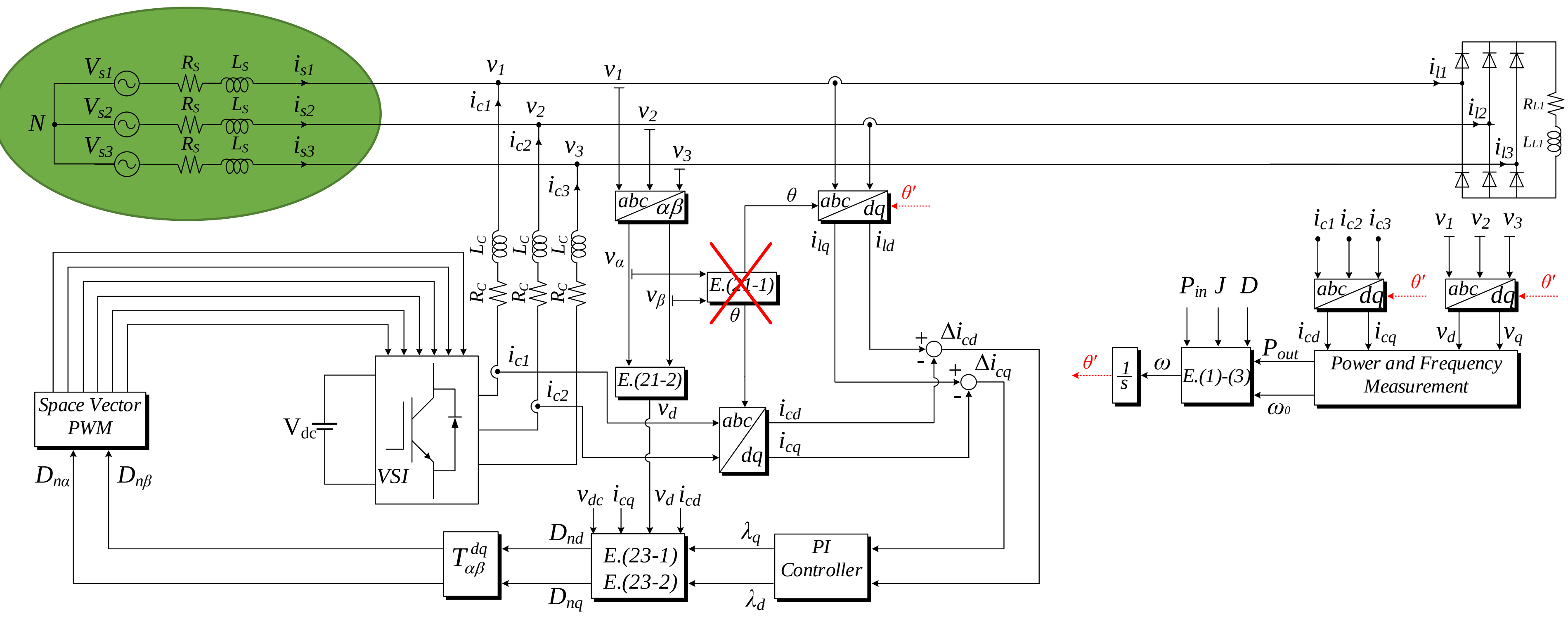
$$P_{in} - P_{out} - D\left(\omega - \omega_0\right) = J\omega\frac{d\omega}{dt} \longrightarrow \frac{d\omega}{dt} = \frac{P_{in} - P_{out} - D\left(\omega - \omega_0\right)}{J\omega} \quad (2)$$

$$\omega = \frac{d\theta}{dt} \rightarrow \theta = \int \omega dt \quad (3)$$

General schematic diagram



Emulation of Virtual Inertia in Control Loop of the Interfaced Converters



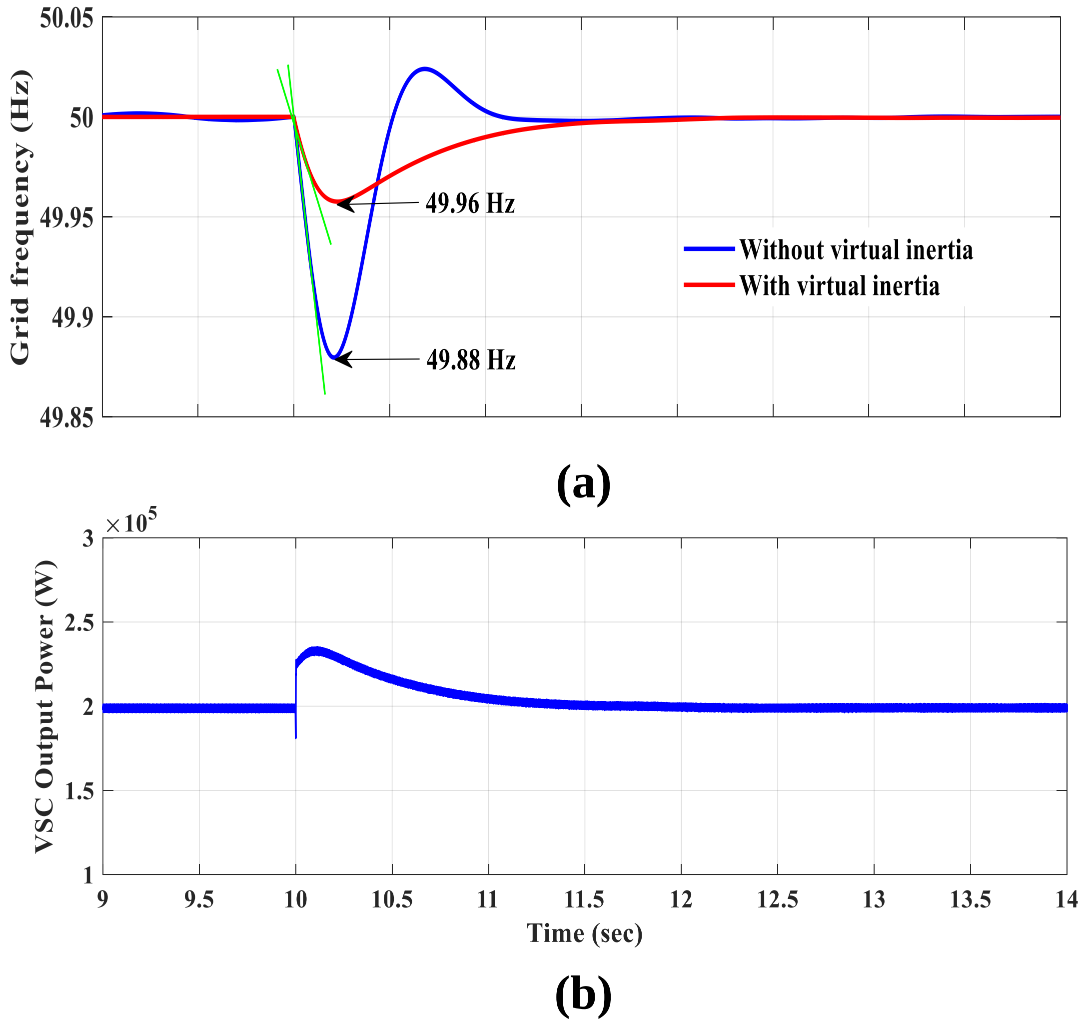


Fig. 2. (a) Grid frequency and (b) VSC output power curves under step-up change in the demand.

Questions and comments are most welcome!