« EMR for Grid-Forming and -Following Inverters with Onshore Electric Ships and Offshore Wind Plant »

Quang-Manh Bui[1], Linh Tran[1], Thanh Vo-Duy[1], Tuyen Vu[2], Bảo-Huy Nguyễn*[1]

[1]CTI Lab4EV, Hanoi University of Science and Technology, Vietnam

[2]Clarkson University, Potsdam, NY, USA

*Corresponding: huy.nguyenbao@hust.edu.vn

ĐẠI HỌC BÁCH KHOA HÀ NỘI
HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY

PTN NGHIÊN CỨU XE ĐIỆN
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« Context & Objective »

EMR for Modeling and Control of Grid-Forming and -Following Inverters

- Context and Objective -

The offshore wind energy at Binh Thuan (Vietnam)

Tan Cang port at Ho Chi Minh city (Vietnam)

Grid-Following Inverter (GFLI)

Grid-Forming Inverter (GFLI)

Inverters-Based Microgrid System

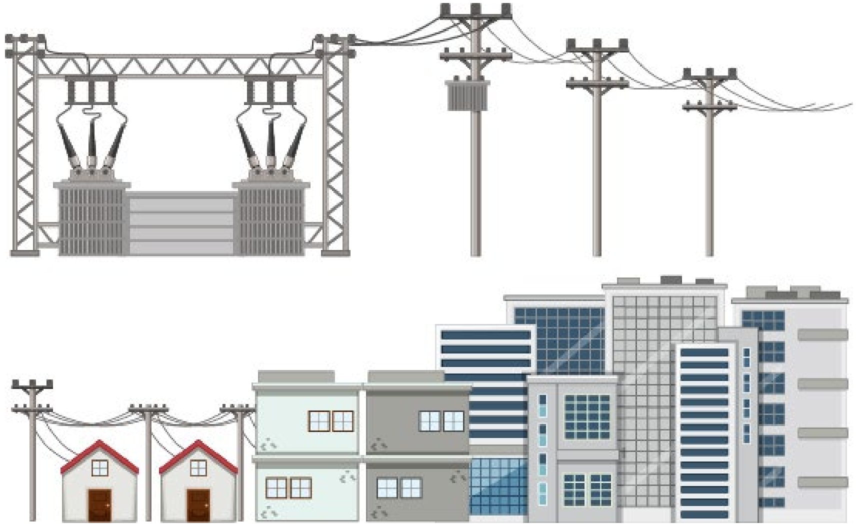
Challenge to the inertia of the power system

Generator

Microgrid Model

Investigate the performance of the model in normal condition

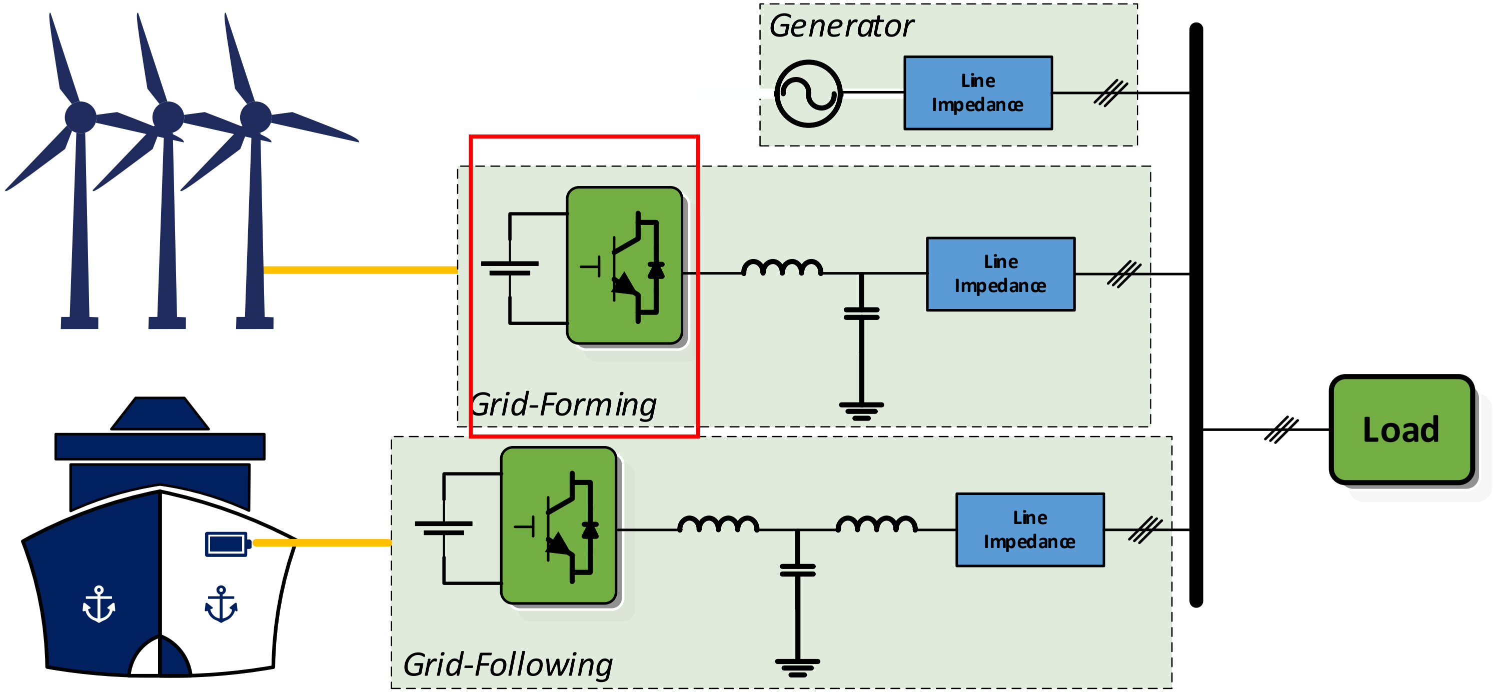
Analyze the frequency deviation of the grid when having a change in power demand



« System Modeling & Control Scheme »

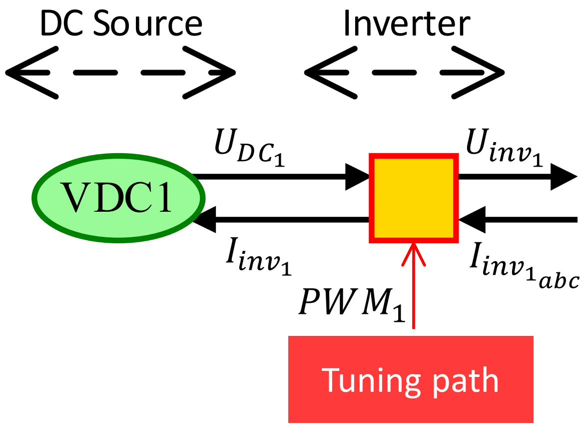
EMR for Modeling and Control of Grid-Forming and -Following Inverters

- System representation using EMR [Bouscayrol 2012] -

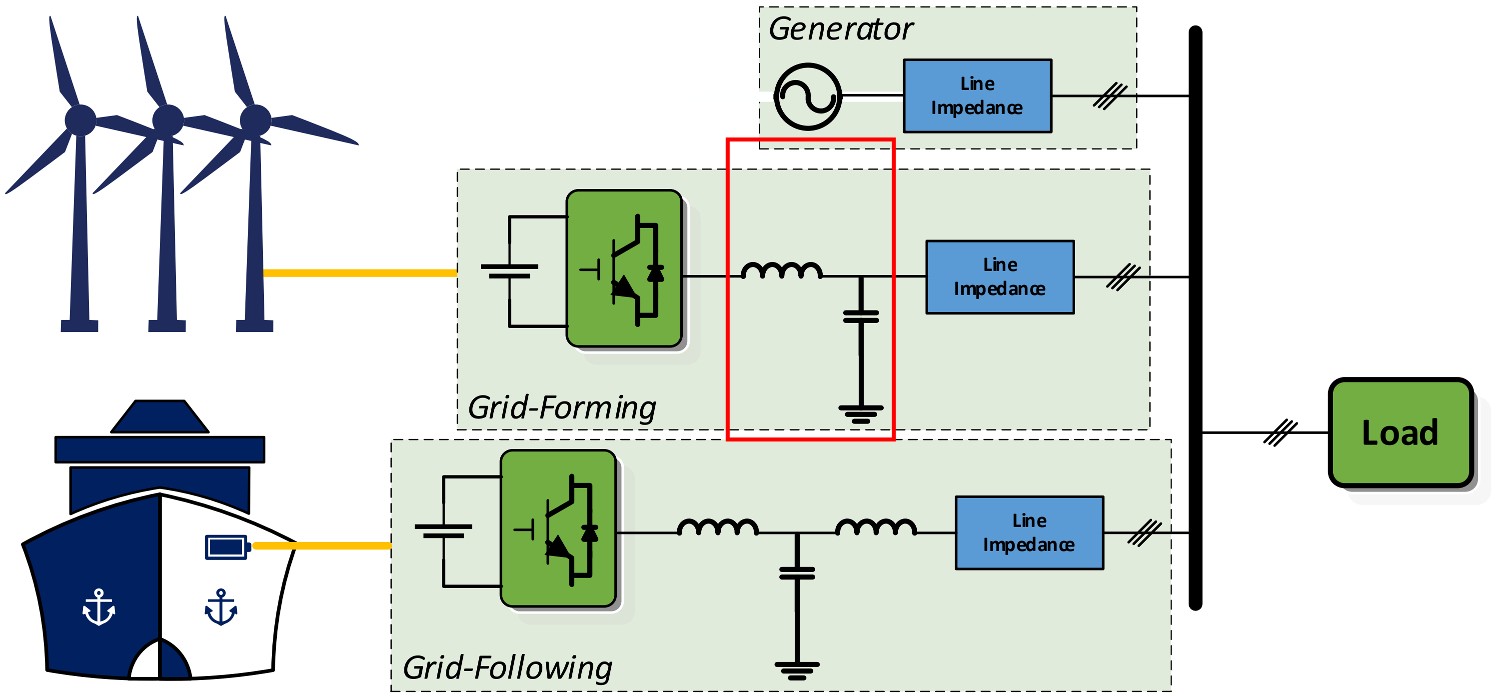


$$\begin{cases} u_{DC_1} = constant \\ i_{inv_1} = common \end{cases}$$

$$\begin{cases} u_{inv_1} = \mathrm{PWM}_1 . \dfrac{u_{DC_1}}{2} \\ i_{inv_1} = \dfrac{\sum \mathrm{PWM}_1 . i_{inv_{1abc}}}{2} \end{cases}$$

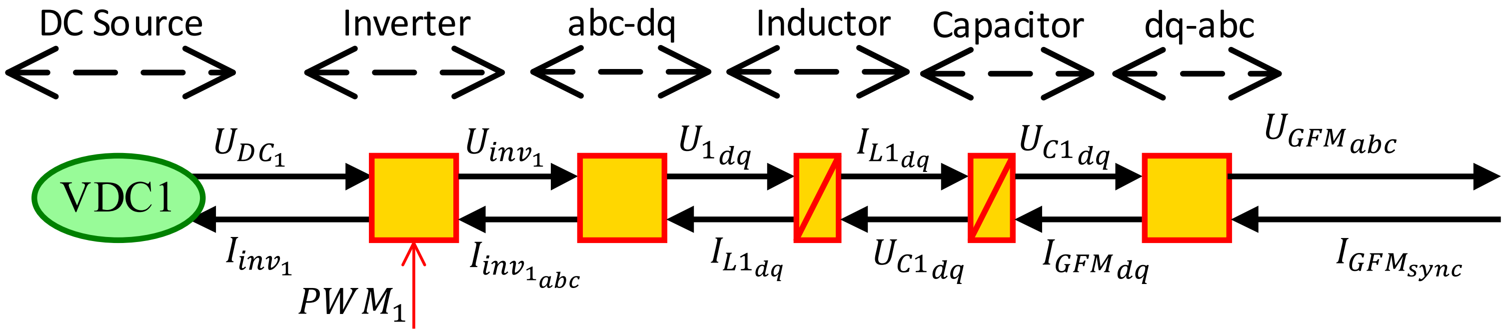


- System representation using EMR -

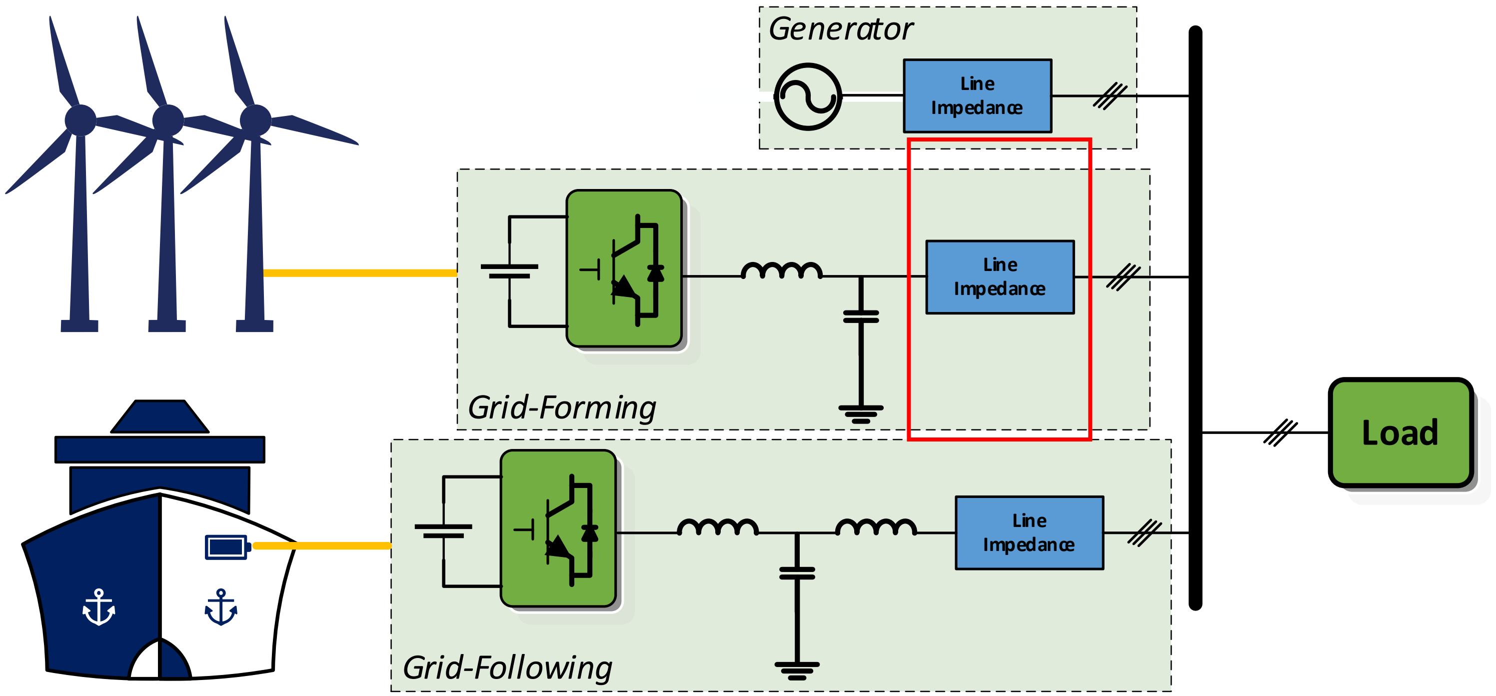


$$\begin{cases} L_1 \dfrac{di_{L1_d}}{dt} = u_{1_d} - u_{C1_d} + w.L_1.i_{L1_q} \\ L_1 \dfrac{di_{L1_q}}{dt} = u_{1_q} - u_{C1_q} - w.L_1.i_{L1_d} \end{cases}$$

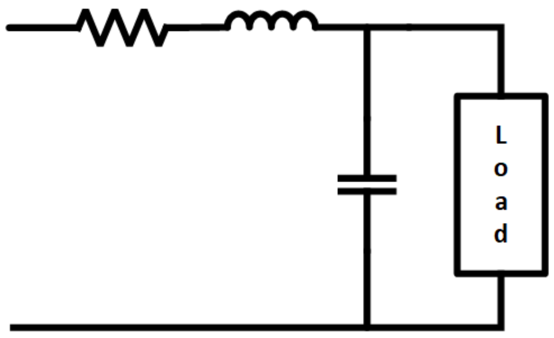
$$\begin{cases} C_1 \dfrac{du_{C1_d}}{dt} = i_{L1_d} - i_{GFM_d} + w.C_1.u_{C1_q} \\ C_1 \dfrac{du_{C1_q}}{dt} = i_{L1_q} - i_{GFM_q} - w.C_1.u_{C1_d} \end{cases}$$

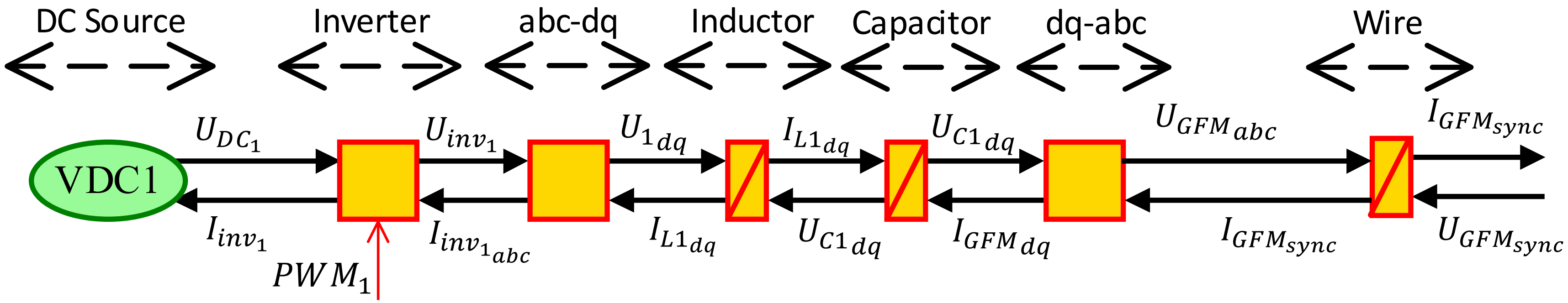


- System representation using EMR -

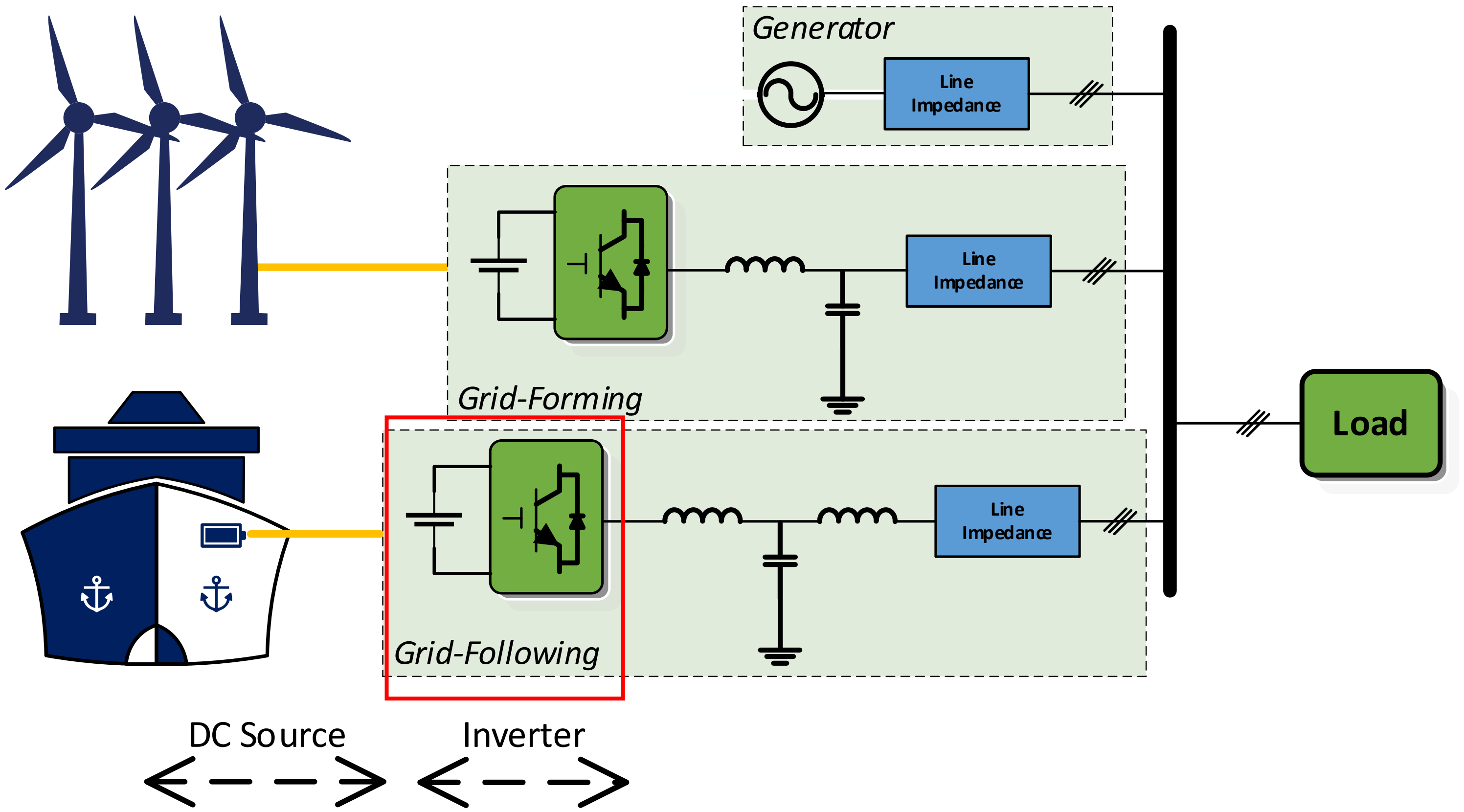


Medium Transmission Line



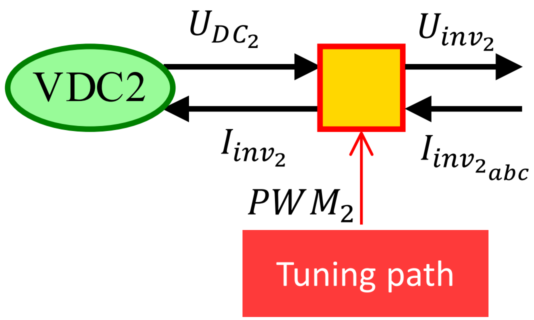


- System representation using EMR -



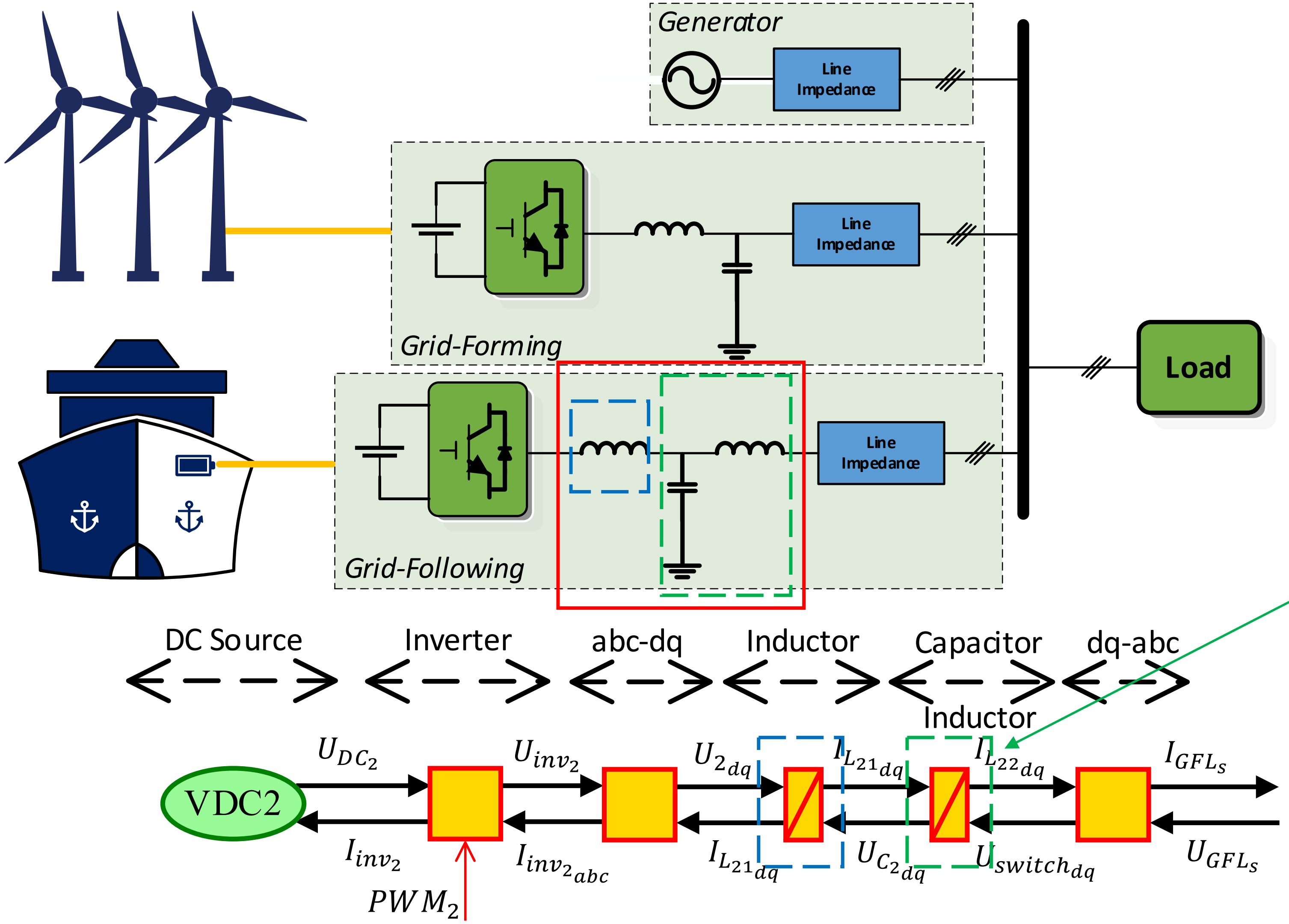
$$\begin{cases} u_{DC_2} = constant \\ i_{inv_2} = common \end{cases}$$

$$\begin{cases} u_{inv_2} = \mathrm{PWM}_2 . \frac{u_{DC_2}}{2} \\ i_{inv_2} = \frac{\sum \mathrm{PWM}_2 . i_{inv_{2abc}}}{2} \end{cases}$$



EMR for Modeling and Control of Grid-Forming and -Following Inverters

- System representation using EMR -



$$C_2 \frac{du_{C_{2d}}}{dt} = i_{L_{21d}} - i_{L_{22d}} + w.C_2.u_{C_{2q}}$$

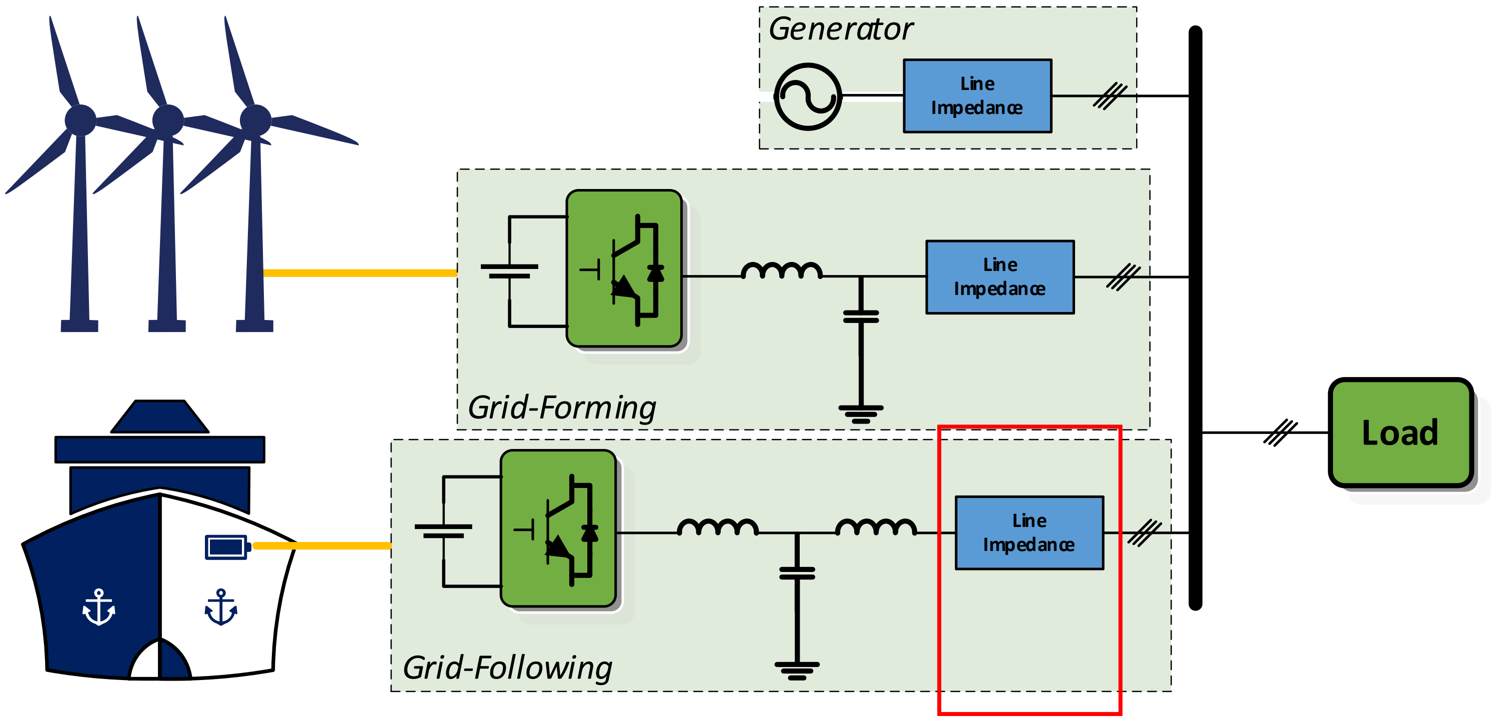
$$C_2 \frac{du_{C_{2q}}}{dt} = i_{L_{21q}} - i_{L_{22q}} - w.C_2.u_{C_{2d}}$$

$$L_{22} \frac{di_{L_{22d}}}{dt} = u_{C_{2d}} - u_{switch_d} + w.L_{22}.i_{L_{22q}}$$

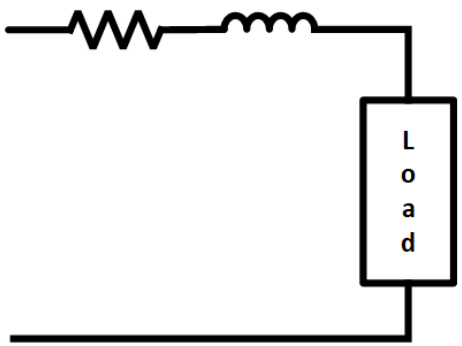
$$L_{22} \frac{di_{L_{22q}}}{dt} = u_{C_{2q}} - u_{switch_q} - w.L_{22}.i_{L_{22d}}$$

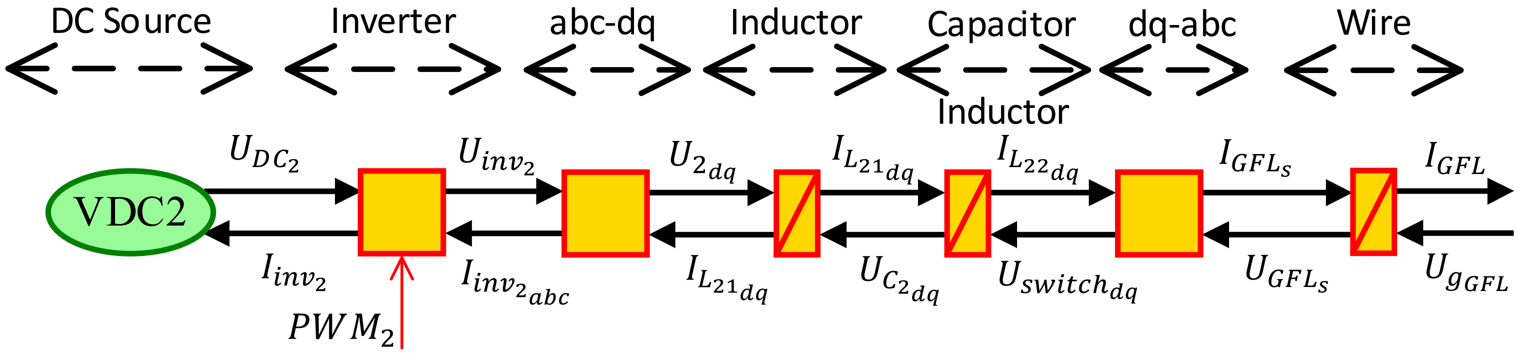
EMR for Modeling and Control of Grid-Forming and -Following Inverters

- System representation using EMR -

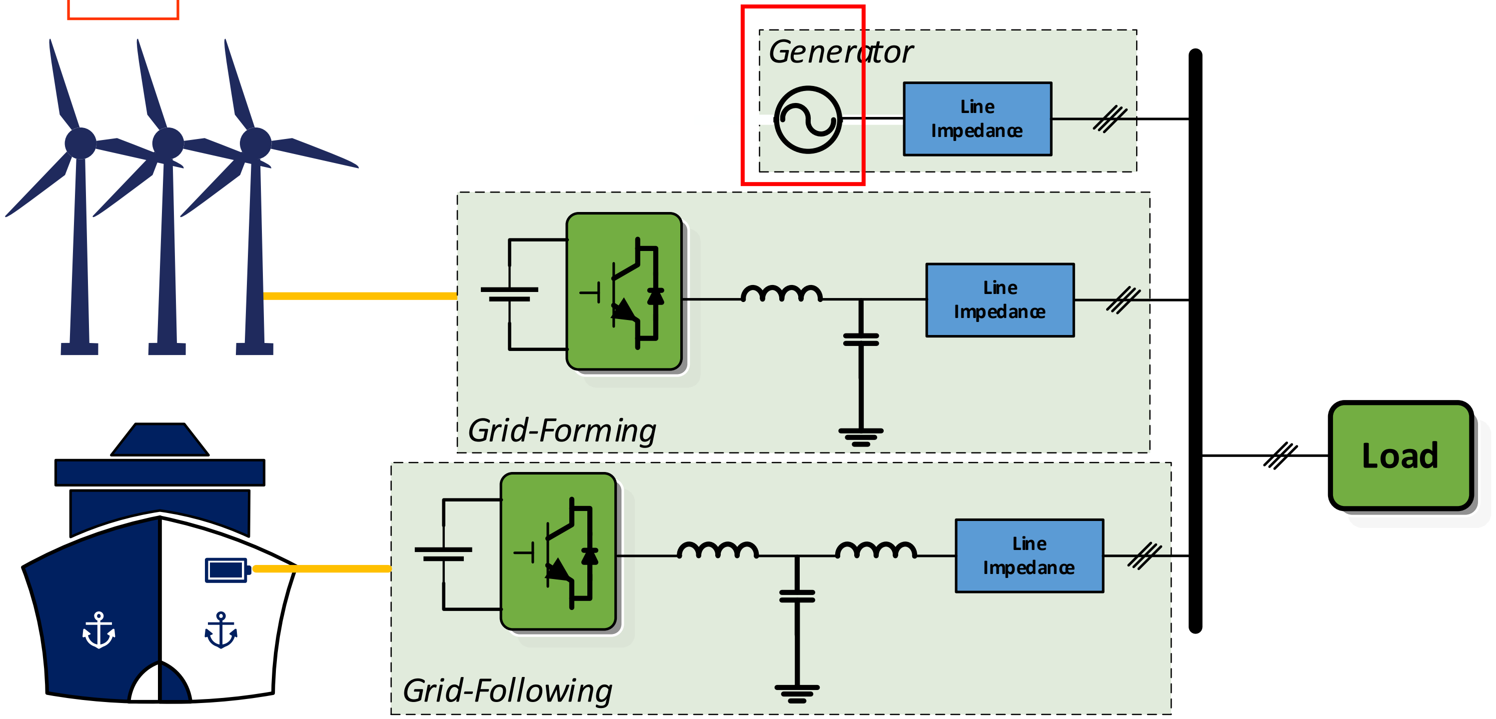


Short Transmission Line





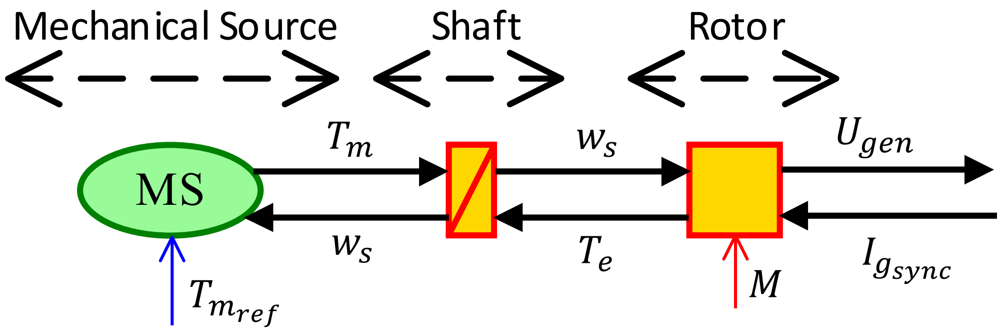
- System representation using EMR -



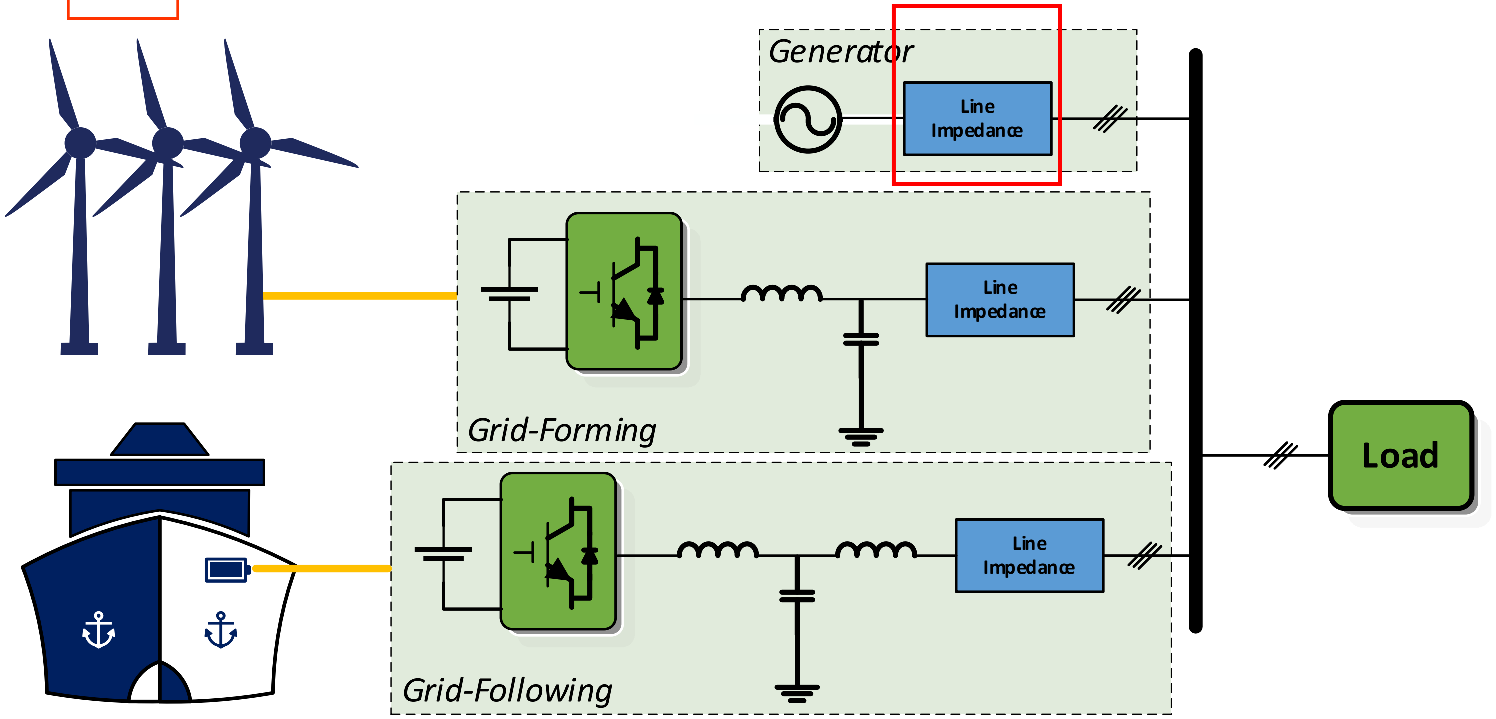
$$T_m = T_{m_{ref}}$$

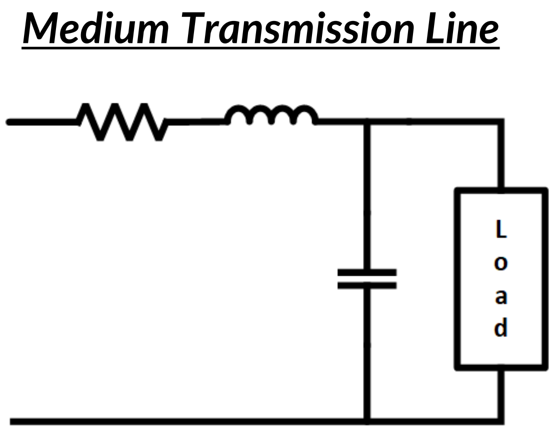
$$J.\frac{dw}{dt} = T_m - T_e$$

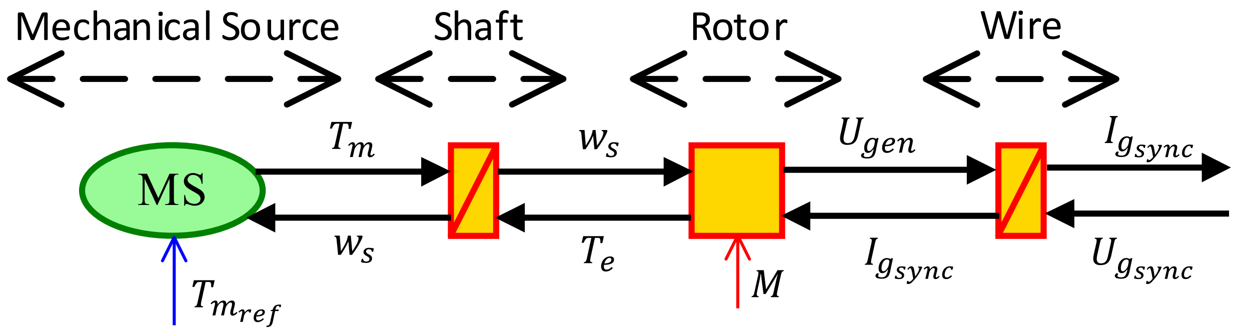
$$\begin{cases} U_{gen} = M_f.I_f.w.\widetilde{\sin}(wt) \\ T_e = p.M_f.I_f.\langle i, \widetilde{\sin}(wt)\rangle \end{cases}$$



- System representation using EMR -

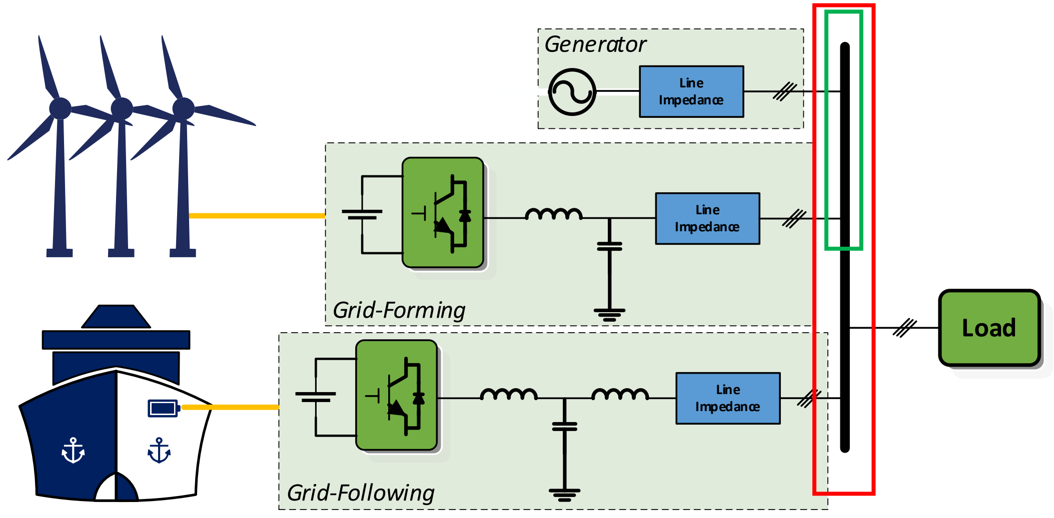


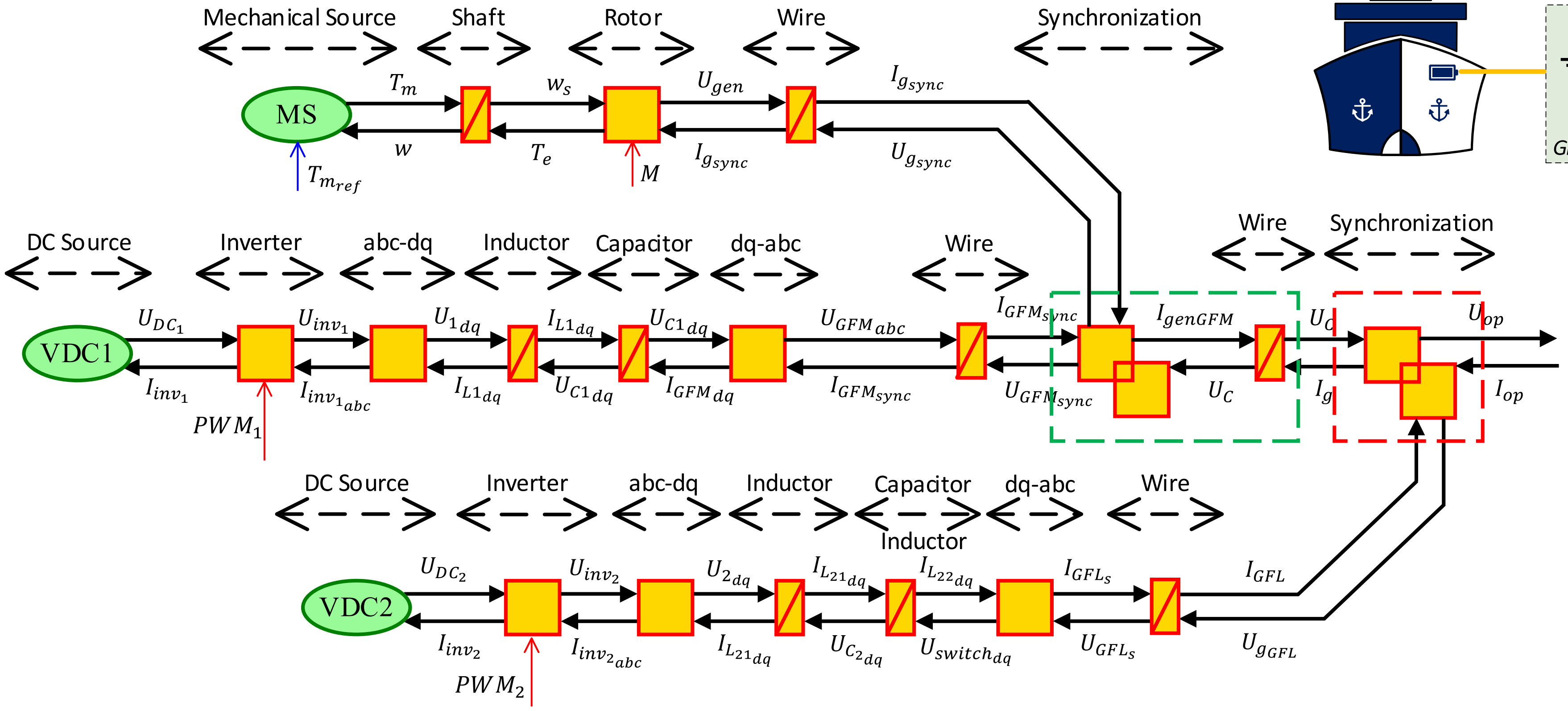




- System representation using EMR -

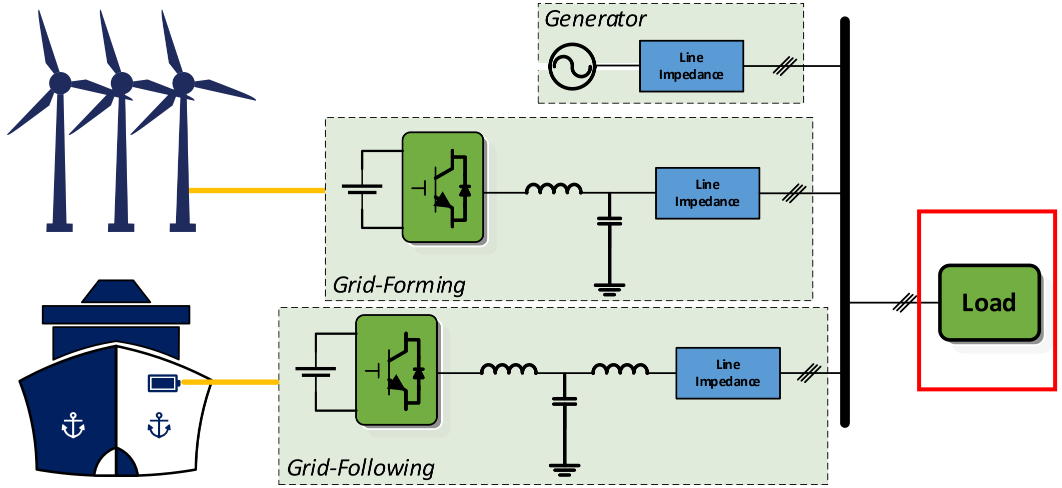
$$i_{gen_{GFM}} = i_{GFM_{sync}} + i_{g_{sync}}$$
$$u_C = u_{GFM_{sync}} = u_{g_{sync}}$$
$$u_{op} = u_C = u_{g_{GFL}}$$
$$i_g = i_{op} - i_{GFL}$$

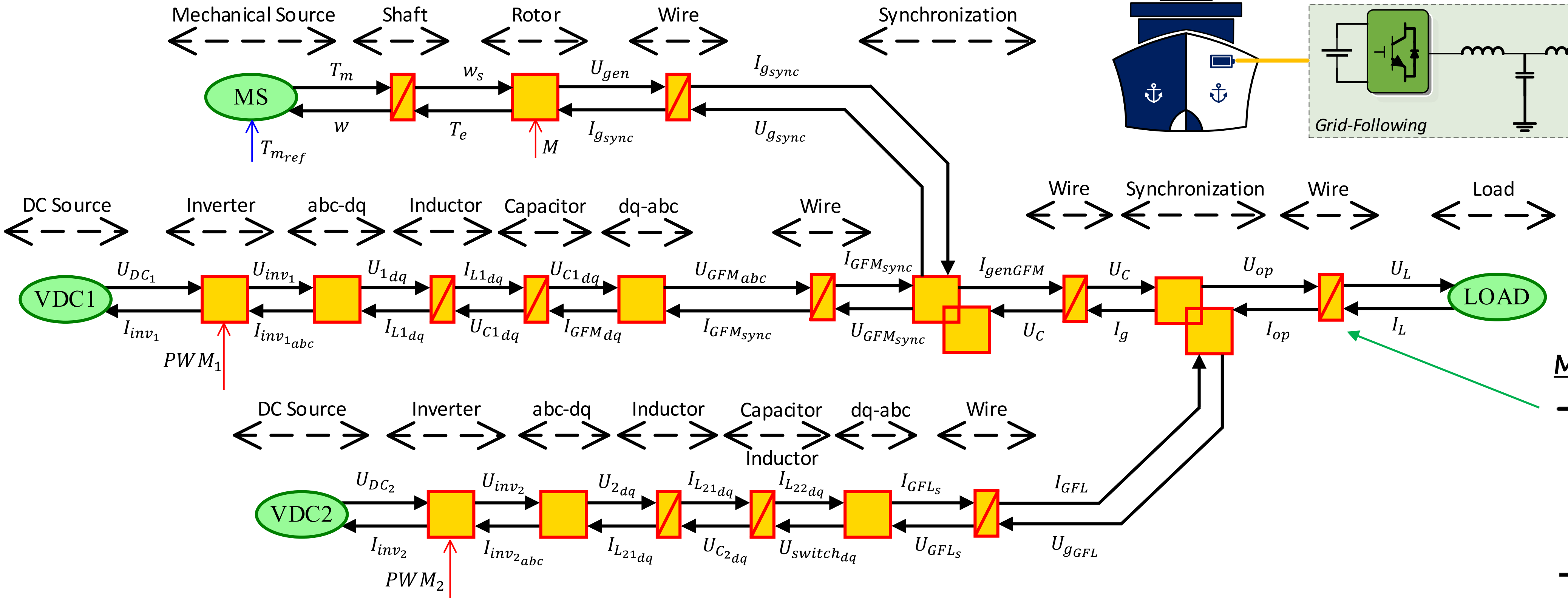




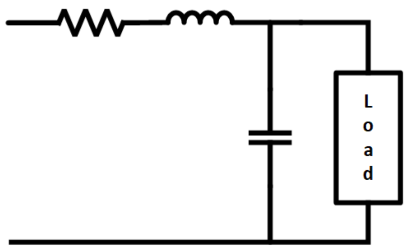
- System modeling using EMR -

$$i_L = \frac{u_L}{\sqrt{3}.R_L}$$





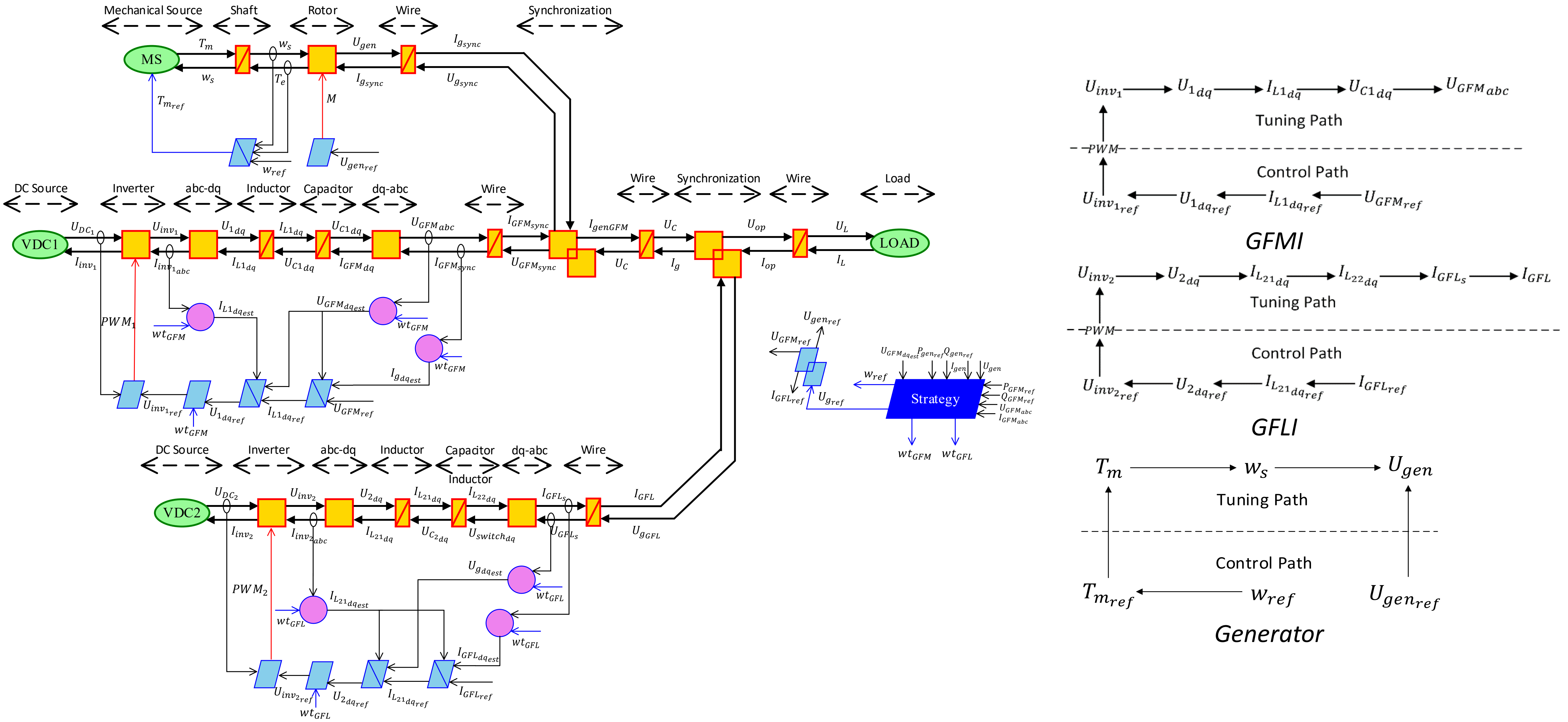
Medium Transmission Line

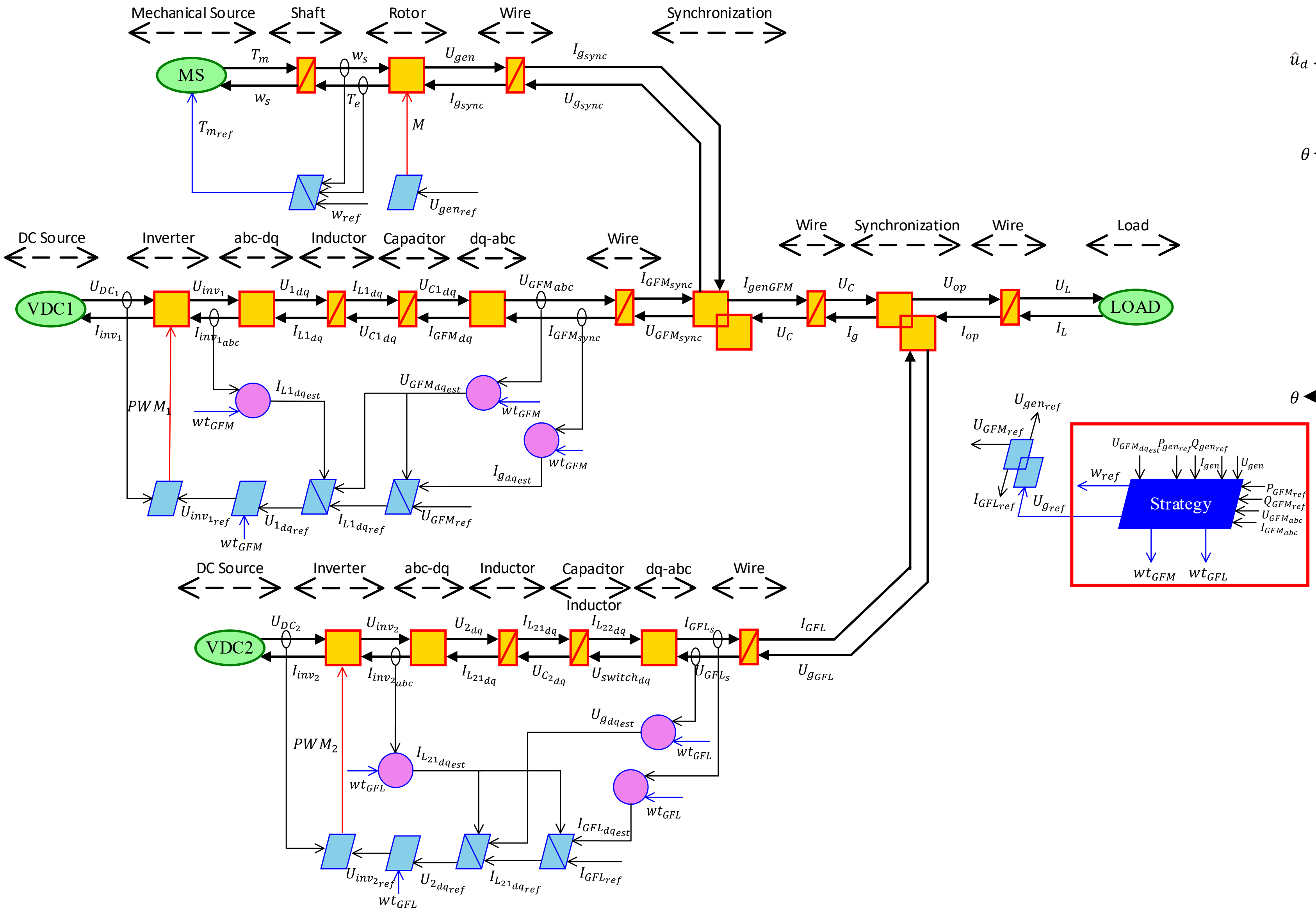


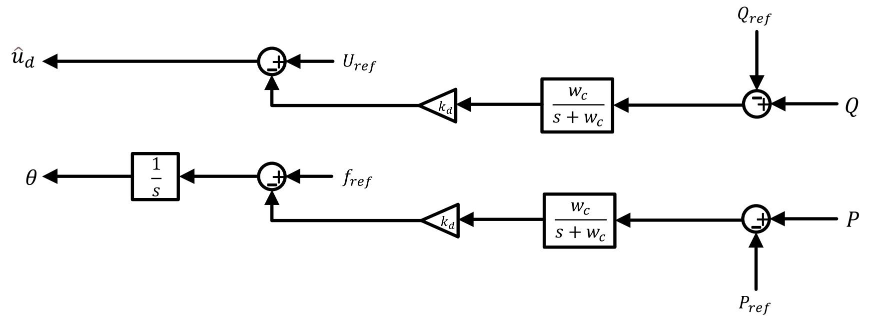
EMR for Modeling and Control of Grid-Forming and -Following Inverters

- Inversion-based control -

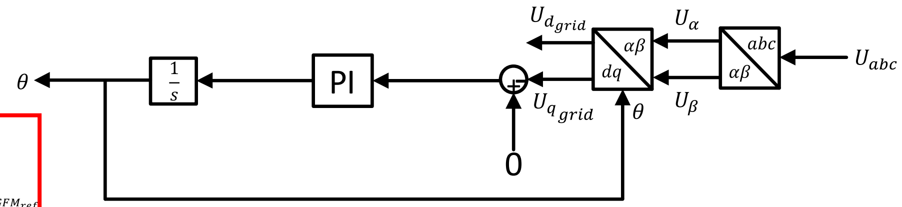
EMR'23, Lille, June 2023







The power control structure



Phase-Locked Loop (PLL) structure

« Frequency Variation Analysis »

Parameters			Values
System	U_{des}	Desired voltage	5 kV
	f	Frequency	50 Hz
	R_L	Load	200 Ω
GFMI	U_{DC_1}	DC source	8 kV
	L_1	Inductor	100 µH
	C_1	Capacitor	500 µF
	P_{ref}	Active power reference	186 kW
	Q_{ref}	Reactive power reference	0 VAr
GFLI	U_{DC_2}	DC source	8 kV
	L_{21}	Inductor	300 µH
	C_2	Capacitor	3.8 µF
	L_{22}	Inductor	300 µH
Generator	J	Inertia moment	$10\,\mathrm{kg\,m^2}$
	p	Number of pole pairs	4
	M_f	Mutual inductance	0.6 H

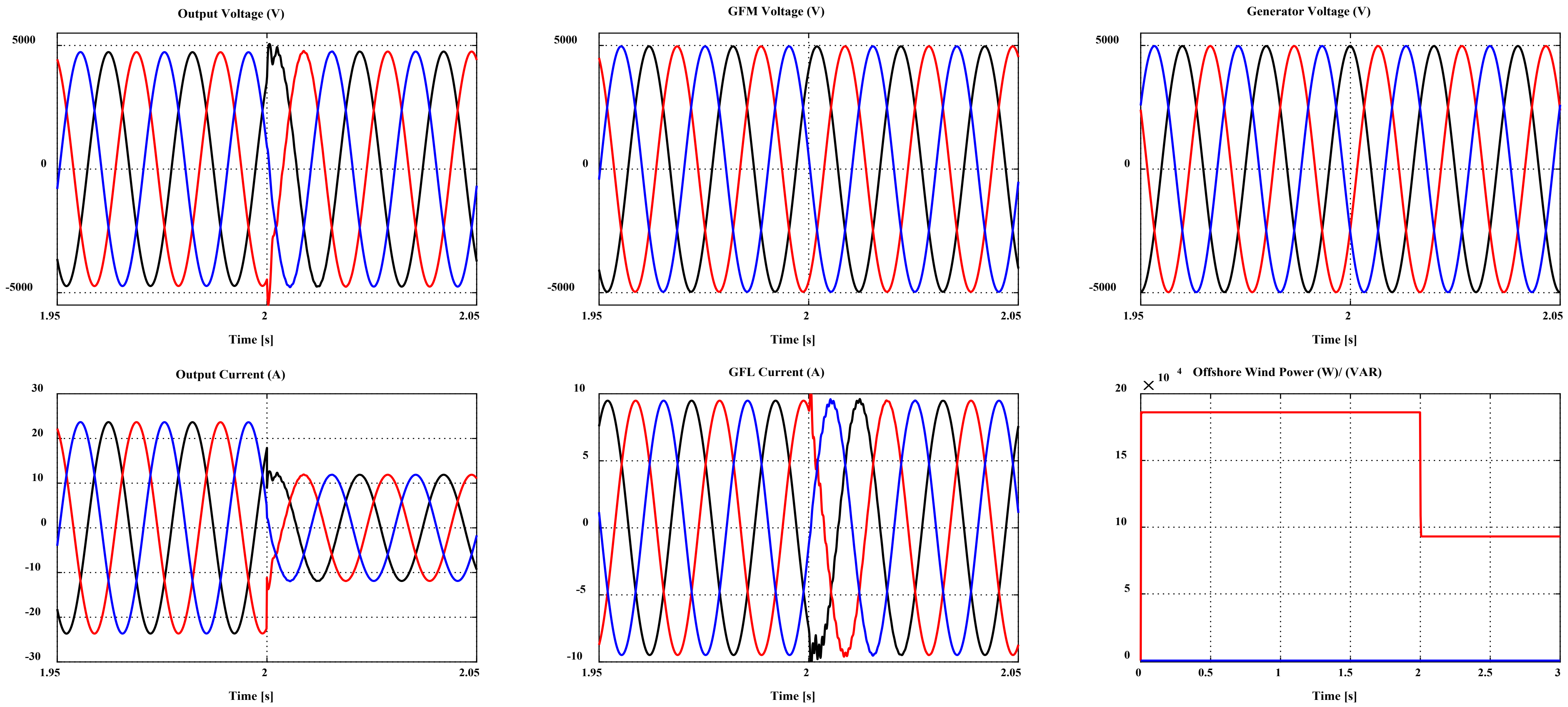
System parameters

Control Parameters			Values
System	T_s	Sampling time	1 µs
	ω_c	Cut-off frequency	1000 Hz
	k_d	Droop gain	0.0001
GFMI	k_{pv}	Proportional gain of the voltage controller	0.1
	k_{iv}	Integral gain of the voltage controller	100
	k_{pi}	Proportional gain of the current controller	30
	k_{ii}	Integral gain of the current controller	200
GFLI	k_{ppll}	Proportional gain of PLL	180
	k_{iv}	Integral gain of PLL	3200
	k_{pif}	Proportional gain of the current controller	30
	k_{ii}	Integral gain of the current controller	200
Generator	k_p	Proportional gain of the moment controller	500
	k_i	Integral gain of the moment controller	50

Control parameters

Scenario

- Initially the GFMI is energized
- Starting the generator
- Injecting the GFL current into the microgrid
- At $t = 2s$ → Simultaneously change the power load demand



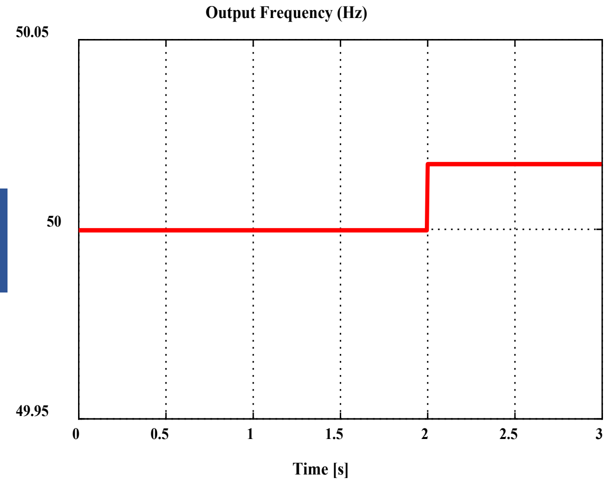
The obtained signals when having a sudden change in power demand

- Line impedance effect on frequency variation -

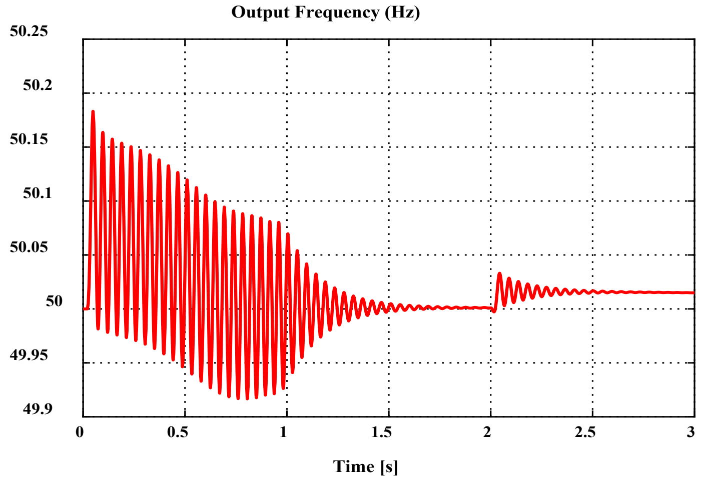
	Short	Medium	Long
R_w	$1.7\,\Omega$	$3.7\,\Omega$	$7.7\,\Omega$
L_w	$0.03\,\mathrm{mH}$	$0.3\,\mathrm{mH}$	$3\,\mathrm{mH}$
C_w	$16.5\,\mathrm{uF}$	$44\,\mathrm{uF}$	$61\,\mathrm{uF}$

Transmission line parameters

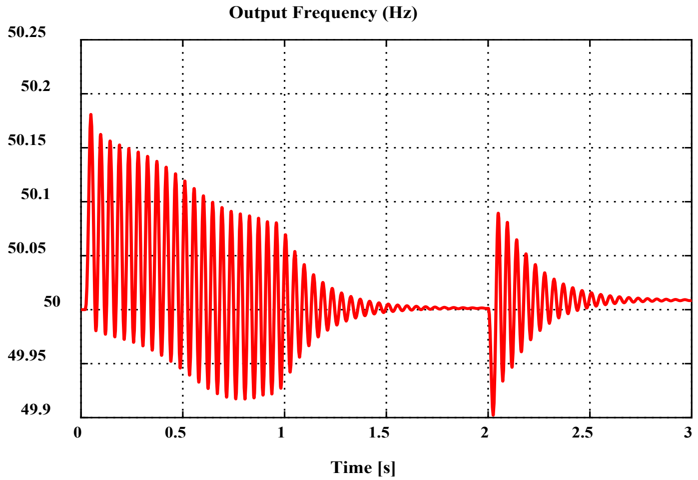
Fast-Fourier Transform (FFT)



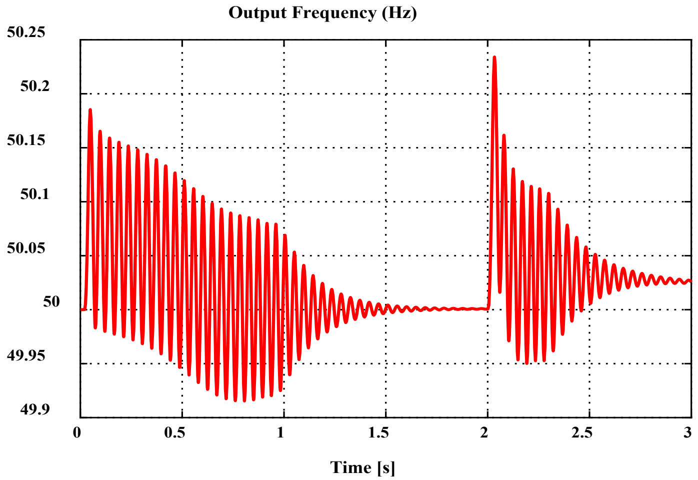
Phase-Locked Loop (PLL)



Short line



Medium line



Long line

« Conclusions & Perspective »

Conclusions

Microgrid system modeling and control

Grid frequency variation analysis

The line impedance effect on the system frequency

Future works

- Optimize control strategy for GFMI (matching control) and GFLI (observer)
- Investigate the feasibility of the proposed seaport system for a larger scale
- Propose solutions to mitigate frequency fluctuation

« Time for Questions »