DTU

Grid Code Compliance of Electrolysis System：LVRT and PFAPR

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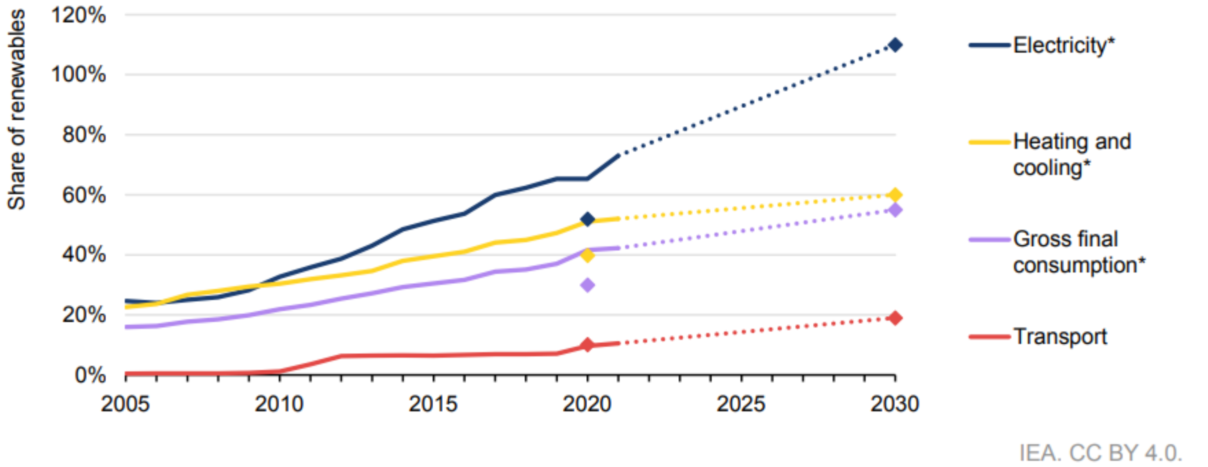
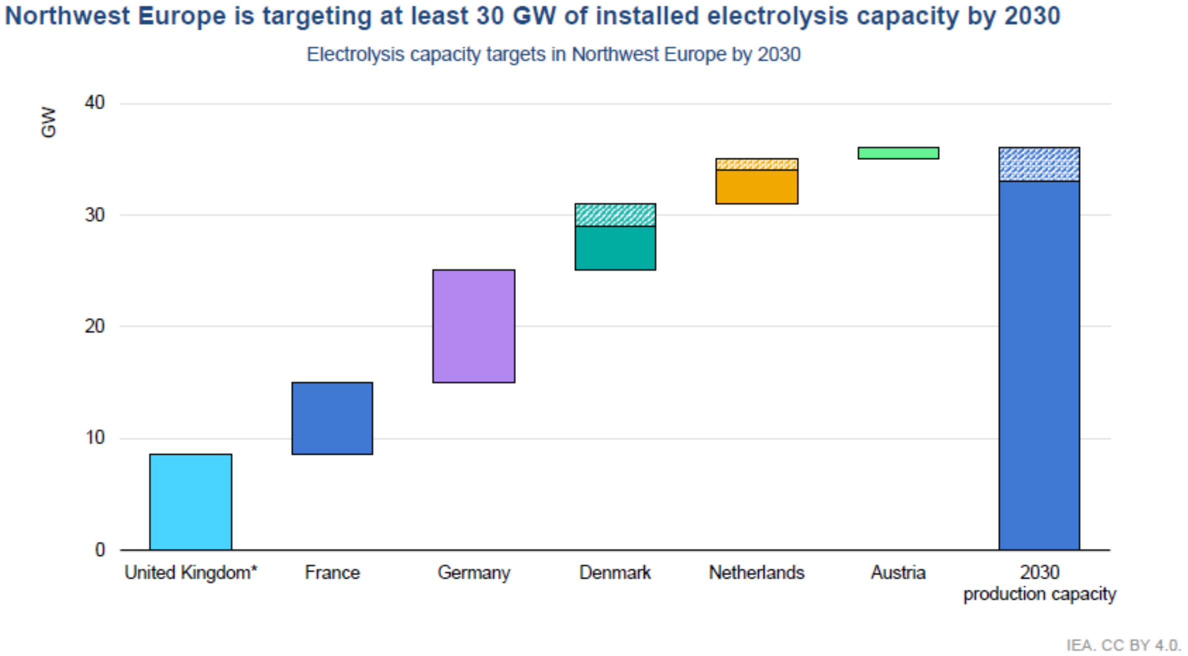
Background

Denmark’s renewable energy targets, trajectories and status, 2005-2030 [1]



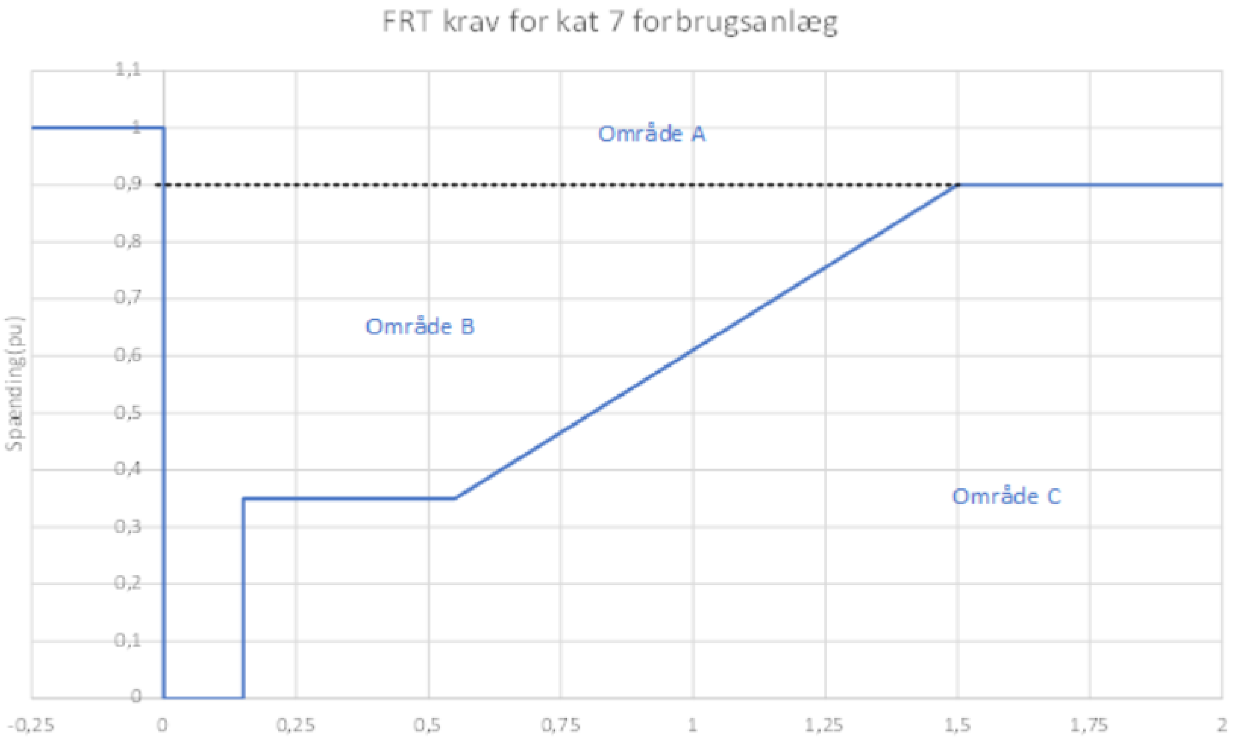
	Current	Trajectories	
Renewable energy share	**2021**	**2020**	**2030**
Gross final energy consumption	34.7%	30%	55%
Electricity	62.6%	51.9%	>100%
Heating and cooling	41.5%	39.8%	60%
Transport	10.5%	10.1%	19%



High proportion of renewable energy vs large-scale hydrogen plant

Grid code compliance

Fault ride through (FRT)



FRT profiles in point-of-connection (PoC)

Spænding (pu)		Tid (s)	
U_{ret}	0	t_{clear}	0,15
U_{clear}	0,35	t_{rec1}	0,15
U_{rec1}	0,35	t_{rec2}	0,55
U_{rec2}	0,90	t_{rec3}	1,5

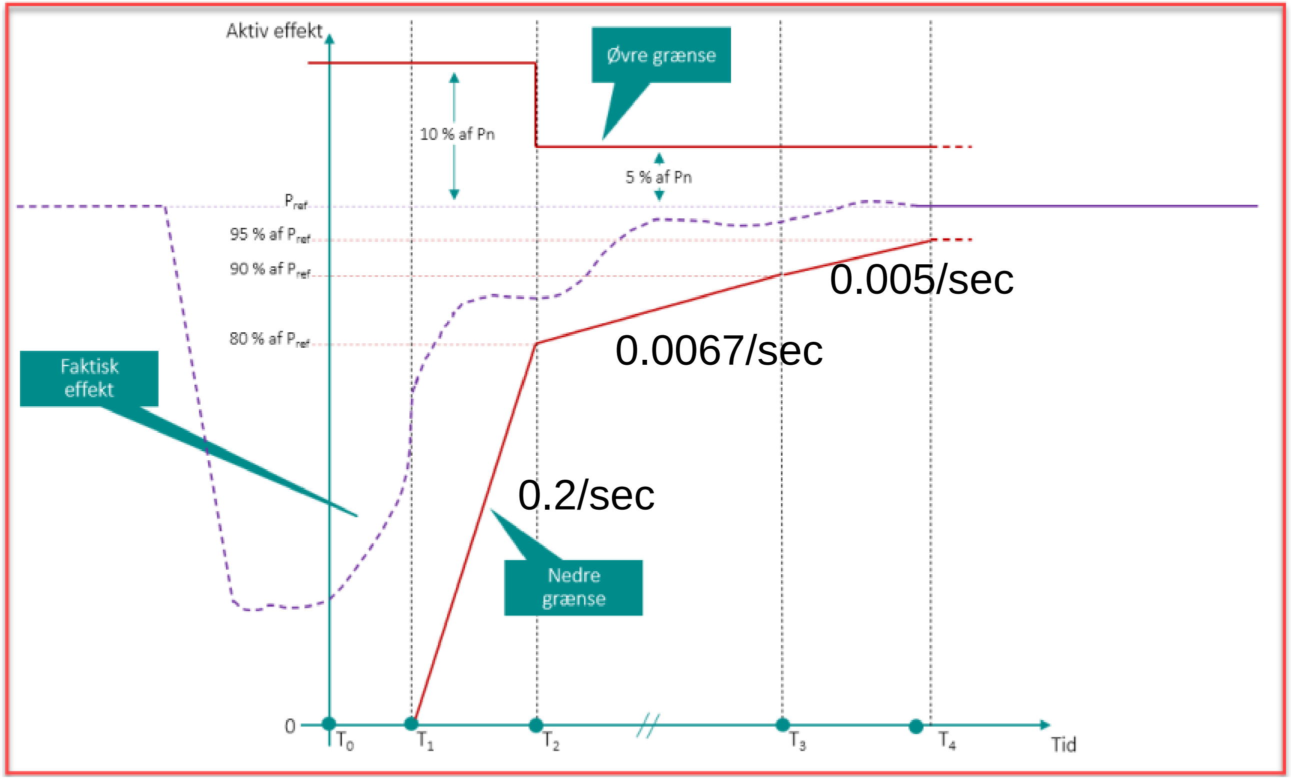
Electrolyser:

Standby/stop

Remain operating

Grid code compliance

Post fault active power recovery (PFAPR)



T0 = time when operating conditions at PCC are back in the range of continued operation.

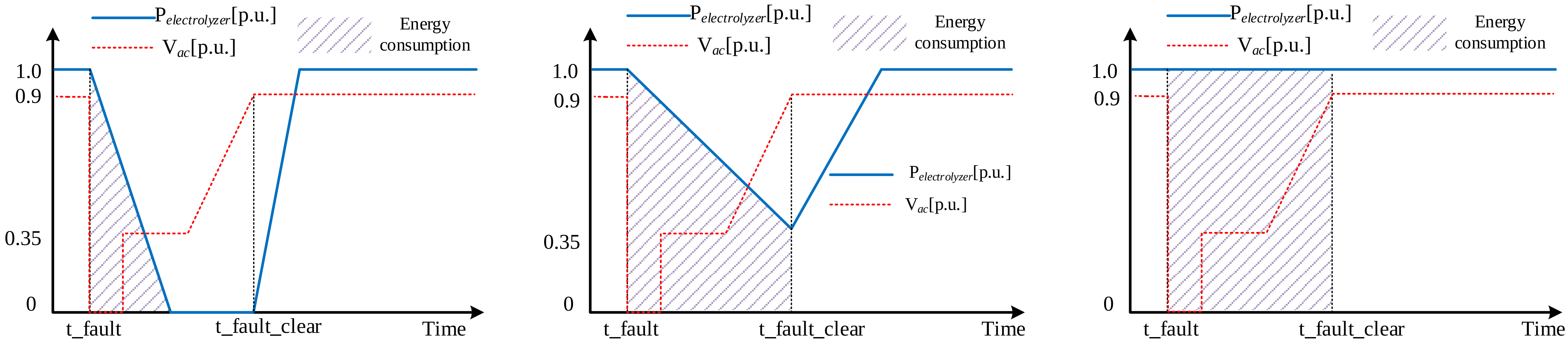
T1 = T0 + 1s

T2 = T1 + 4s

T3 = T2 + 15s

T4 = T3 + 10s

Potential behavior of electrolyser



Behavior I: Fully power response

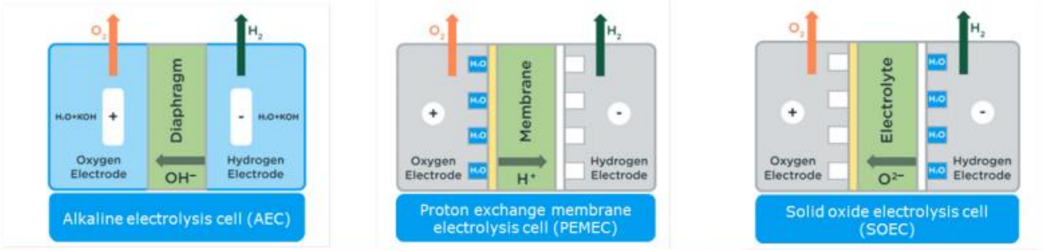
Best case

Behavior II: Partially power response

Behavior III: Zero power response

Worst case

Features of Electrolysis system



Type	Low temperature		High temperature
	Alkaline electrolysis cell (AEC)	Proton exchange membrane electrolysis cell (PEMEC)	Solid oxide electrolysis cell (SOEC)

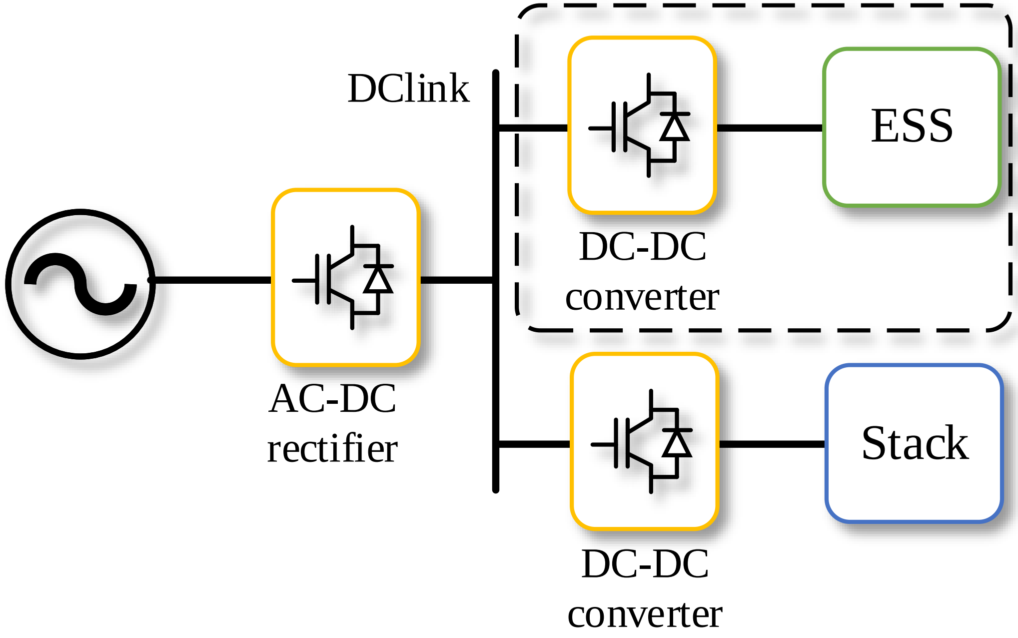
	AEC	PEMEC	SOEC
Cold start-up time (from 0 to 100%) [minutes]*	< 80	0.5	600
Warm start-up time (from 0 to 100%) [seconds]*	240 (60-300)	< 10	600
Power response signal [seconds]*	< 1-5	< 1-5	< 1-5
Load range per electrolyser system (%)*	15-100	5-130	30-125

*Ramboll own data

The three primary electrolyser technologies: AEC, PEMEC, and SOEC[2]

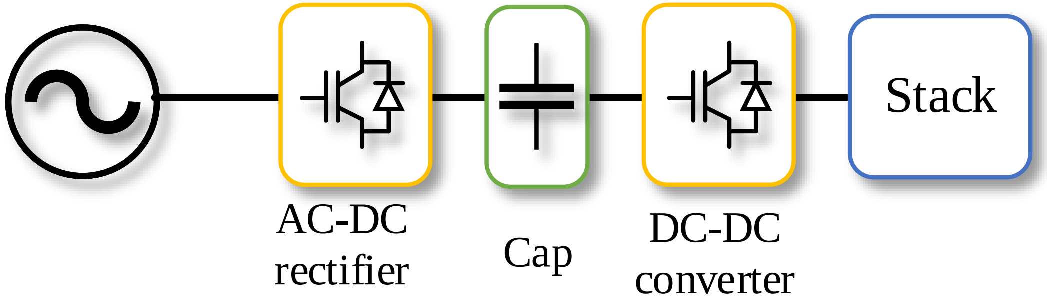
Solutions to LVRT and PFAPR

With BESS



Mismatch between power and energy[3]

Increasing DC link capacitor



Techno-Economic analysis

Parameters of bus capacitor

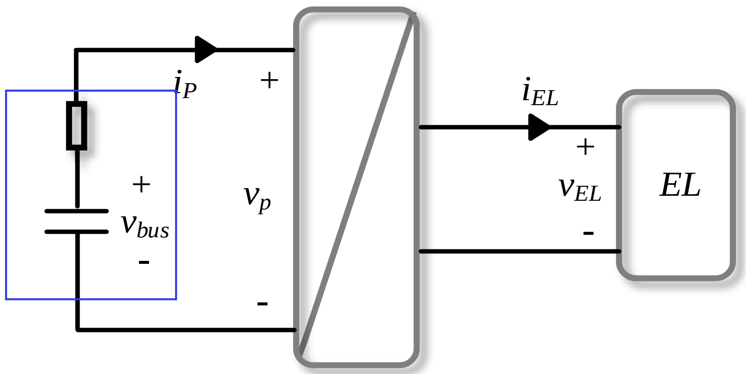
	Lithium Ion Capacitor(LIC)	Super-capacitor(SC)
C_{sm}	62F	3000F
R_{sm}	39mΩ	0.29mΩ
V	180 V	2.7 V

System description and assumptions

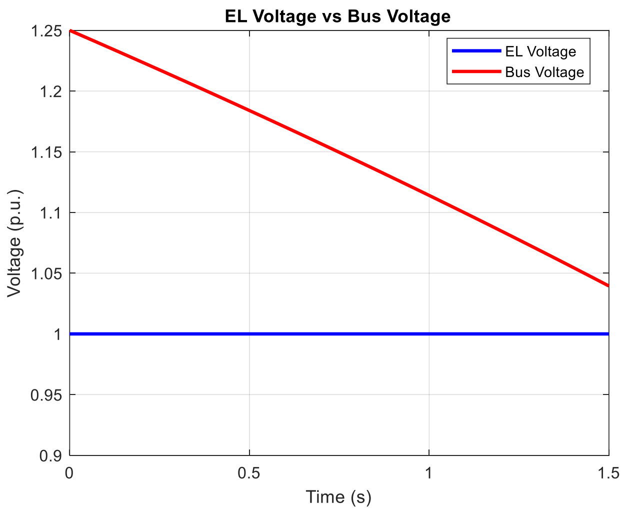
Parameters of electrolyser

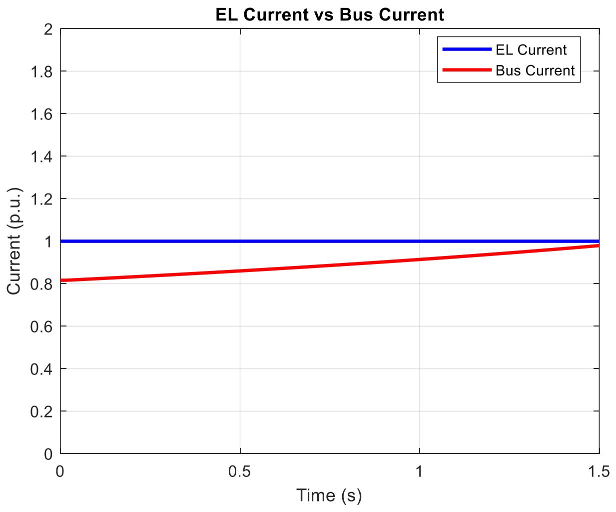
Parameter	V_{res}	R_{EL}	i_{EL}	Power
Value	600 V	0.4 Ω	0~1000A	1 MW

The supercapacitors can be series for high voltage



Structure of converter and electrolyser





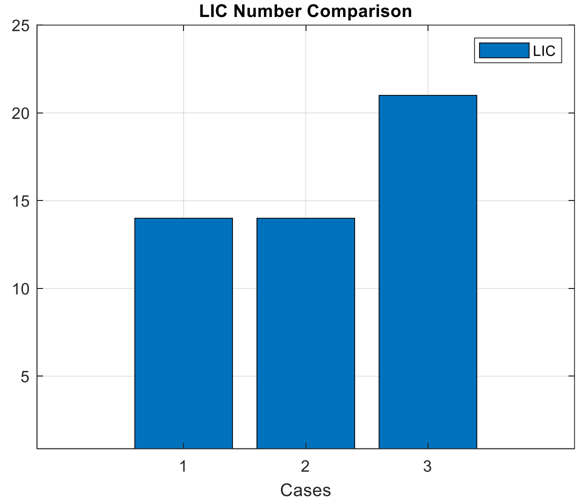
Techno-Economic analysis

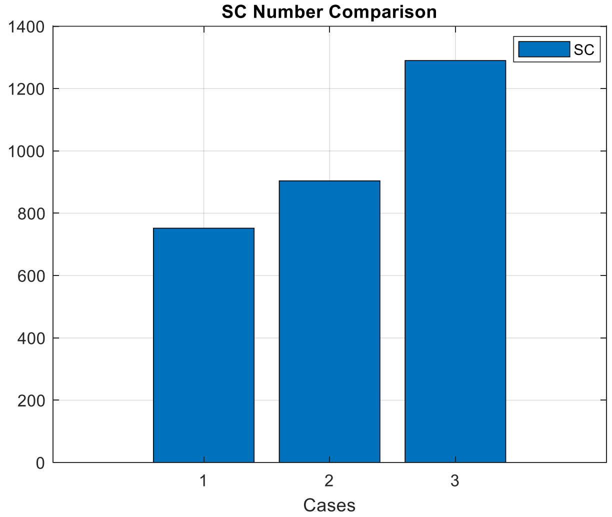
Effects of unit capacitor capacity

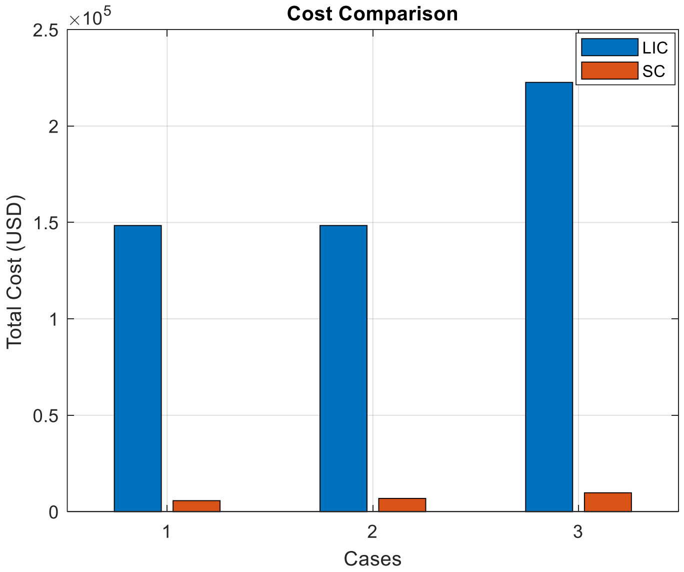
Case1: 1 basic capacitor

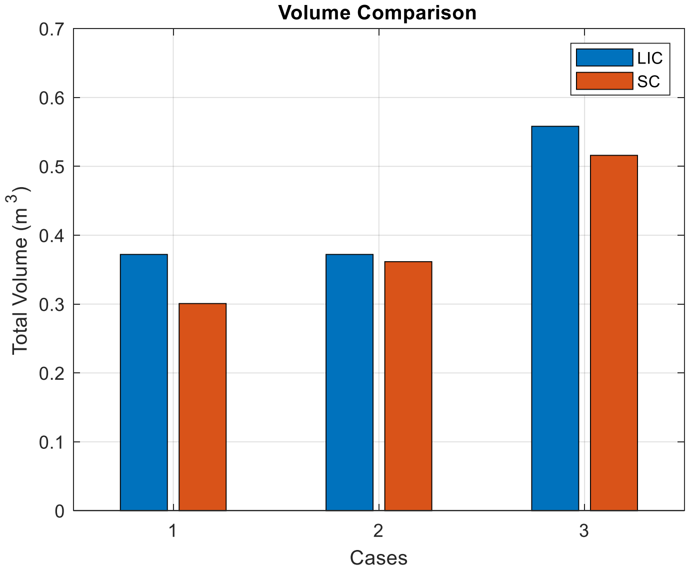
Case2: 2 paralleled capacitor

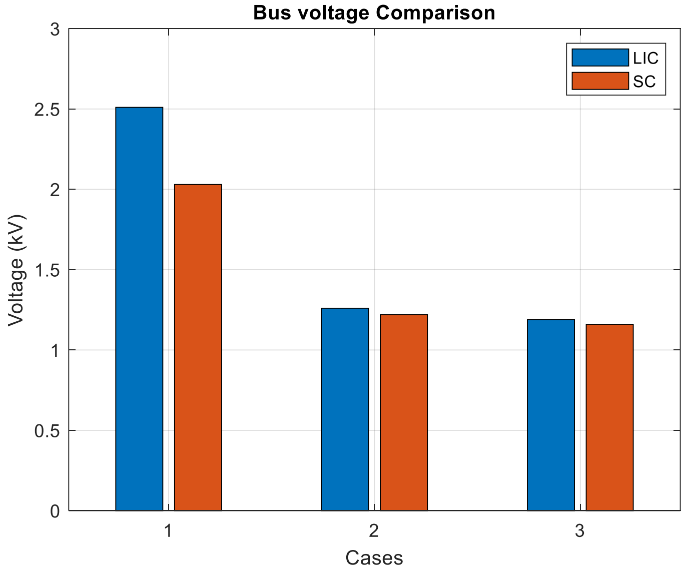
Case3: 3 paralleled capacitor











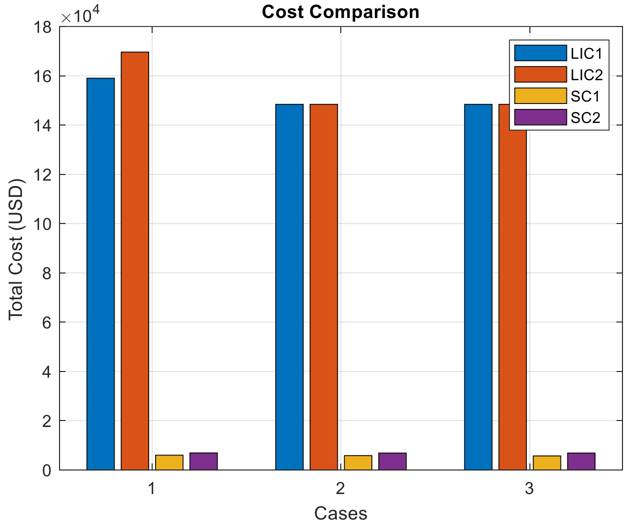
Techno-Economic analysis

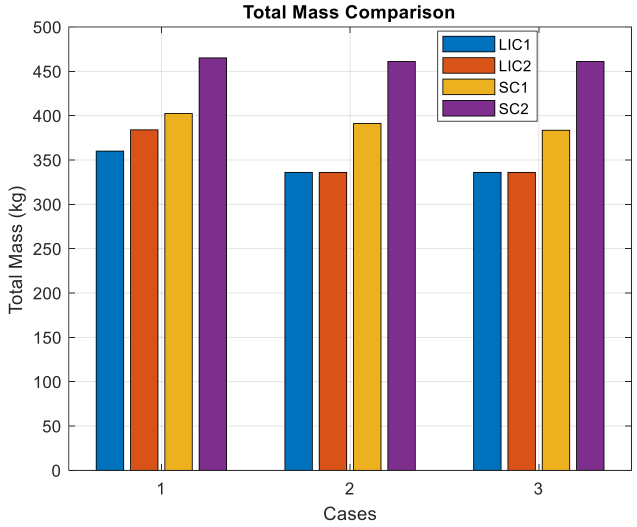
Effects of converter efficiency

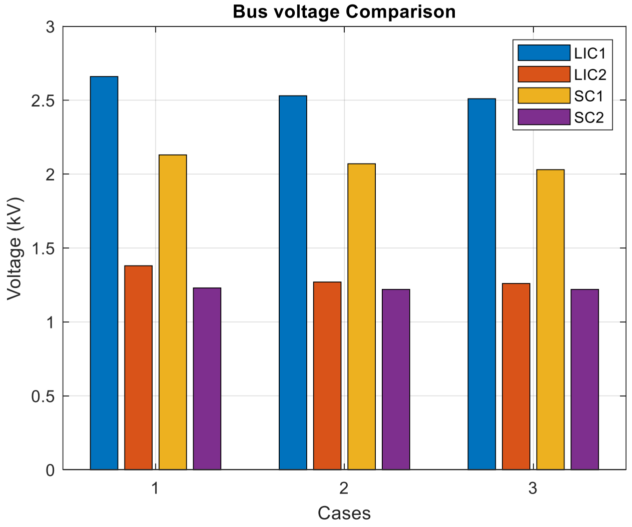
Case1: η=0.95

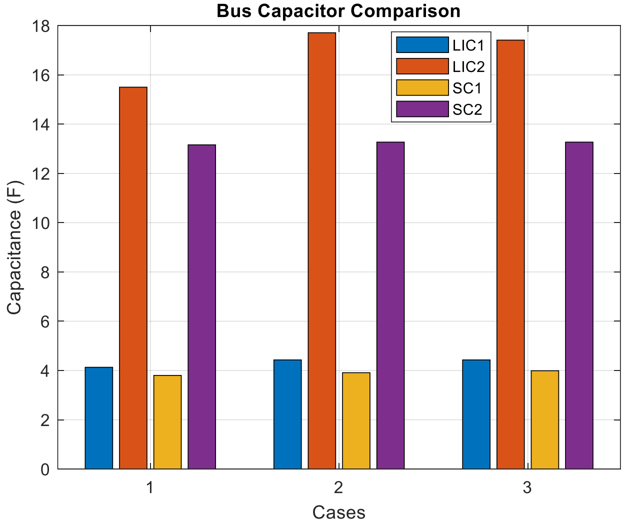
Case2: η=0.98

Case3: η=1









Techno-Economic analysis

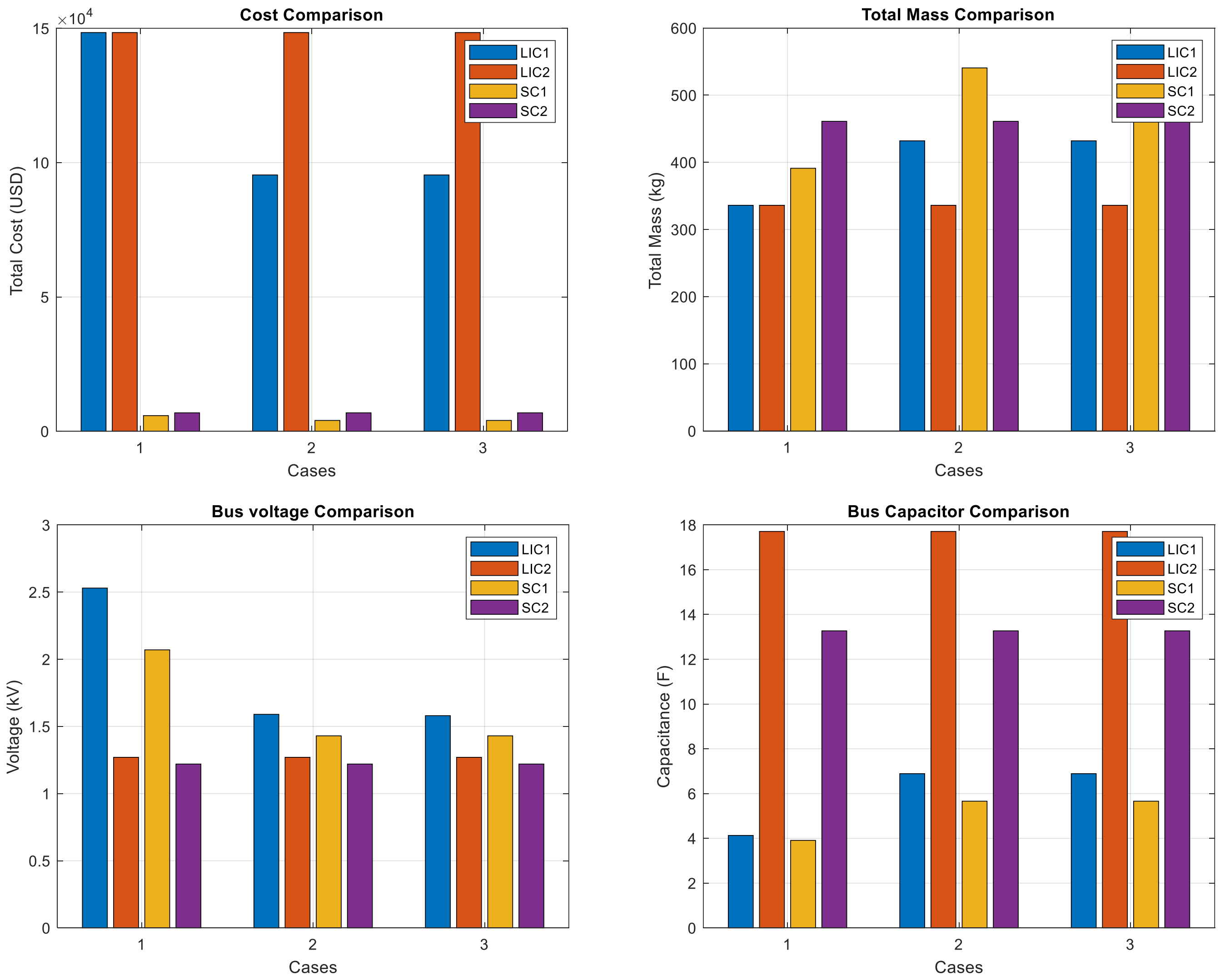
Effects of converter peak current

η=0.98

Case1: KC=1.2

Case2: KC=1.5

Case3: KC=2.0



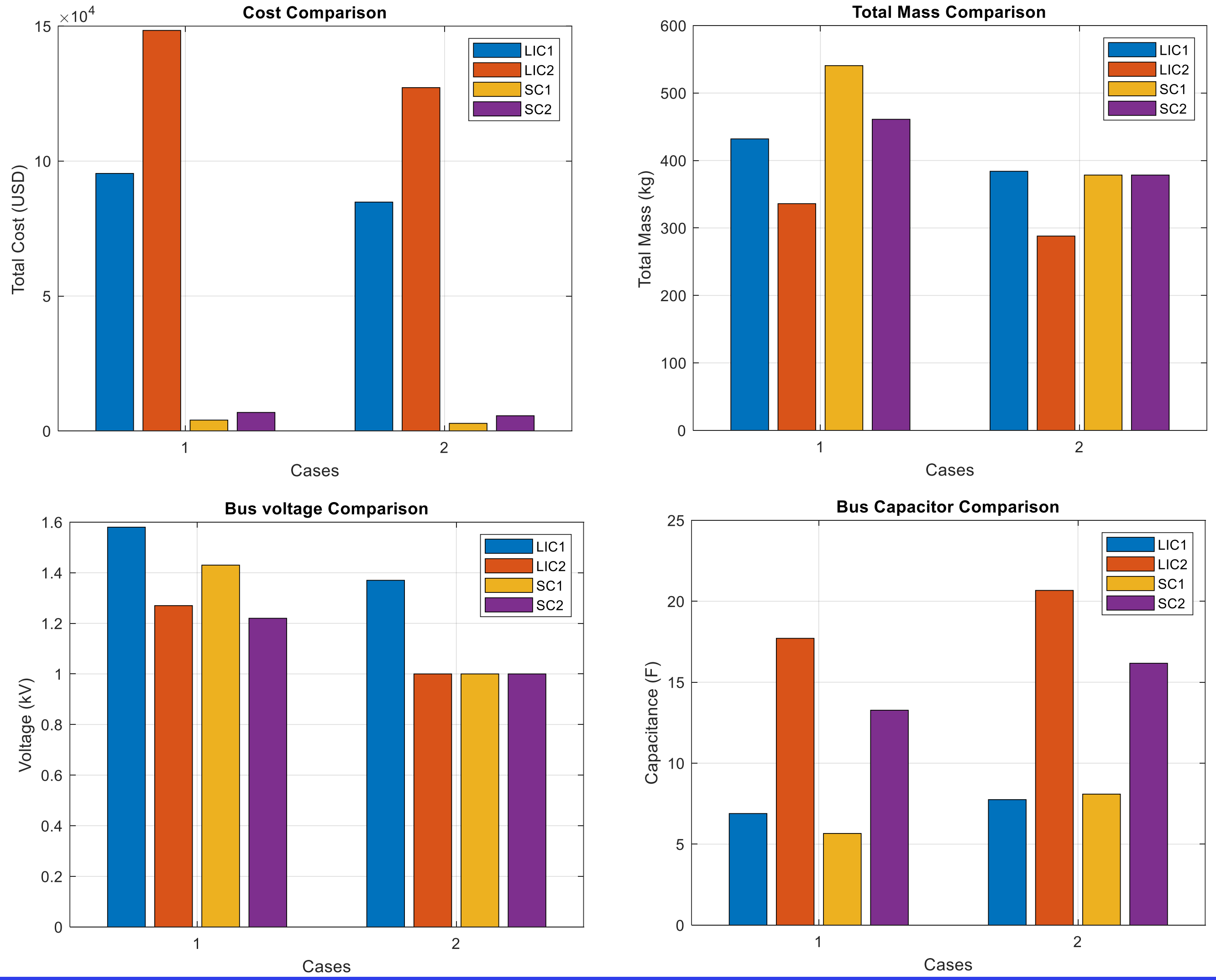
Techno-Economic analysis

Effects of converter type

ŋ=0.98 KC=2.0

Case1: Step-down converter

Case2: Step-up/down converter



Techno-Economic analysis

Comprehensive comparison

ŋ=0.98

KC=2.0

SUD based case has lower bus voltage

Conclusions

- Ramping rate of electrolyser limits to achieve LVRT and PFAFR
- Increasing dc-link capacitor is a potential solution
- Simply increasing the capacitance value has limited effect, while improving the performance of the converter will yield more benefits.

Reference

1. IEA. Denmark 2023 Energy Policy review.
2. Danish Energy Agency. Renewable fuels Technology descriptions and projections for long-term energy system planning.
3. Saha et al. Enabling LVRT Compliance of Electrolyzer Systems,2023

Thanks !