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Transmission Grid Solutions to Allow the Deployment of Wind Offshore Plants in Portugal

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APREN

Objectives

1) Propose and evaluate **technical solutions to connect large wind off-shore plants to the RNT** considering a total installed capacity of **10 GW** (horizon 2040)

    i. HVAC

    ii. HVDC

2) Identify the **main transmission reinforcement corridors** or the **needs of additional reinforcements of the RNT**

    i. **Base assumptions**: Transmission grid configuration (PDIRT-E) 2022-2031

3) **Characterization of additional losses at** RNT as a result of the connection of the wind off-shore plants for the different solutions.

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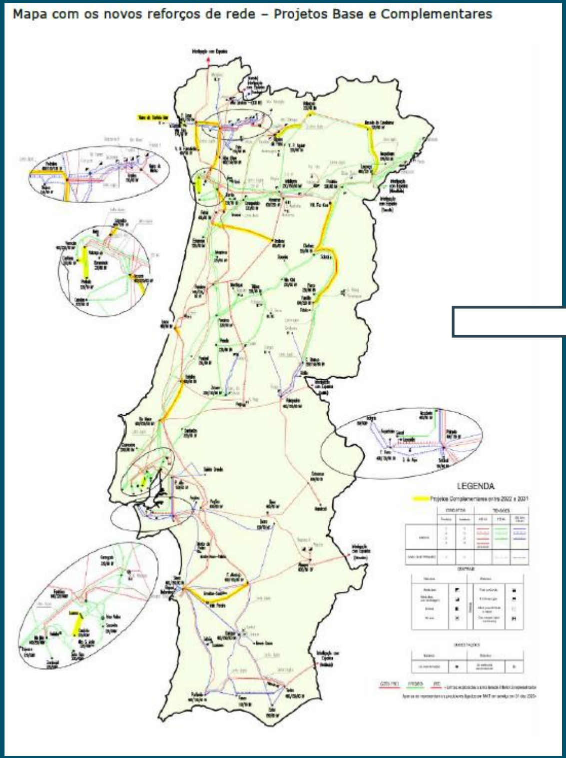
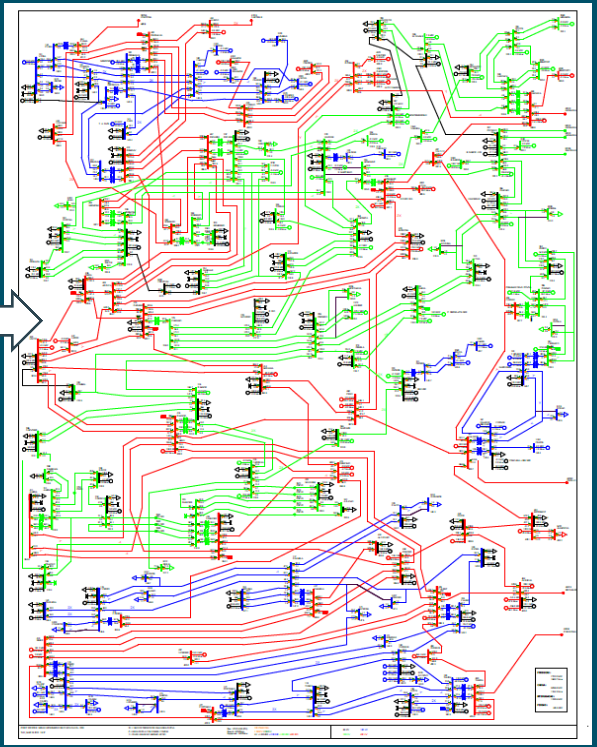
Data Assumptions - Transmission Network Model

- **Provided by REN:** based on the most recent public data available by 2023 - **PDIRT 2022-31 predicted investments** (base and complementary projects) **as well as further investments identified by REN** to accommodate ~1400 MVA of additional load in Sines and future solar PV agreements already approved before 2030





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Generation Installed Capacity per Technology

- Installed capacity (ambition scenario) – RMSA

Tecnologia (MW)	2022	2025	2030	2035	2040
Grandes Térmicas*	3 829	3 829	2 839	2 054	0
Outras Térmicas	0,5	0,5	0,5	0,5	0,5
Total Térmica	*3 829*	*3 829*	*2 839*	*2 054*	*0*
Cogeração não renovável	741	814	777	491	0
Cogeração renovável	460	734	779	880	1 199
Total Cogeração	*1 201*	*1 548*	*1 556*	*1 371*	*1 199*
Grandes Hídricas	7 411	7 577	7 577	7 787	7 787
das quais reversíveis	*3 593*	*3 593*	*3 593*	*3 593*	*3 593*
Pequenas Centrais Hídricas (< 30 MW)	620	620	620	620	620
Total Hídrica	*8 032*	*8 198*	*8 198*	*8 408*	*8 408*
Eólica onshore	5 544	6 300	10 400	11 650	12 900
da qual para produção de H2	0	444	1 159	1 159	1 159
Eólica offshore	25	25	2 000	6 000	10 000
da qual para produção de H2	0	0	1 975	5 977	9 221
Total Eólica	*5 569*	*6 325*	*12 400*	*17 650*	*22 900*
Resíduos Sólidos Urbanos	77	82	112	85	42
Biomassa (s/ cogeração)	221	251	344	260	129
Biogás (s/ cogeração)	83	88	121	91	45
Fotovoltaico (PV)	1 477	6 085	14 897	21 481	28 066
da qual para produção de H2	0	0	8 812	10 616	17 374
Fotovoltaico Concentração (CPV)	15	15	15	15	15
Solar Térmico Concentrado (CSP)	0	0	600	600	600
Total Solar	*1 492*	*6 100*	*15 512*	*22 097*	*28 681*
Ondas	0	2	200	200	200
Geotermia	0	34	51	77	56
Produção Distribuída**	1 033	3 178	5 475	9 653	13 148
Fotovoltaico (PV)	1 018	3 161	5 458	9 637	13 131
Hídrica	0,2	1,7	1,7	1,7	1,7
Eólica	4	4	4	4	4
Biomassa	6,3	6,3	6,3	6,3	6,3
Biogás	3,6	3,6	3,6	3,6	3,6
Ondas/Marés	0	1	1	1	1
Armazenamento	0	0	990	4 839	8 994
TOTAL	21 536	29 636	47 798	66 784	83 803
do qual Renovável	*16 966*	*24 992*	*44 182*	*64 239*	*83 802*
do qual Não-Renovável	*4 570*	*4 643*	*3 616*	*2 545*	*0*

* Capacidade máxima

** Inclui Miniprodução, Microprodução, Unidades de Pequena Produção (UPP) e Unidades de Produção para Autoconsumo com injeção na rede (UPAC)

Technology	MW 2022	MW 2040
Fossil Gas	3829	0
Hydro Water Reservoir	1488	1678
Hydro Run-of-river and poundage	2331	2517
Hydro Pumped Storage	3593	3593
Small hydro (≤ 30 MW)	620	620
Wind onshore	5544	12900
Wind offshore	25	10000
Solar (PV + CPV + CSP)	1492	28681
CHP + Biomass + Biogas	1505	1373
Others	77	298
Total Capacity	**20504**	**61660**

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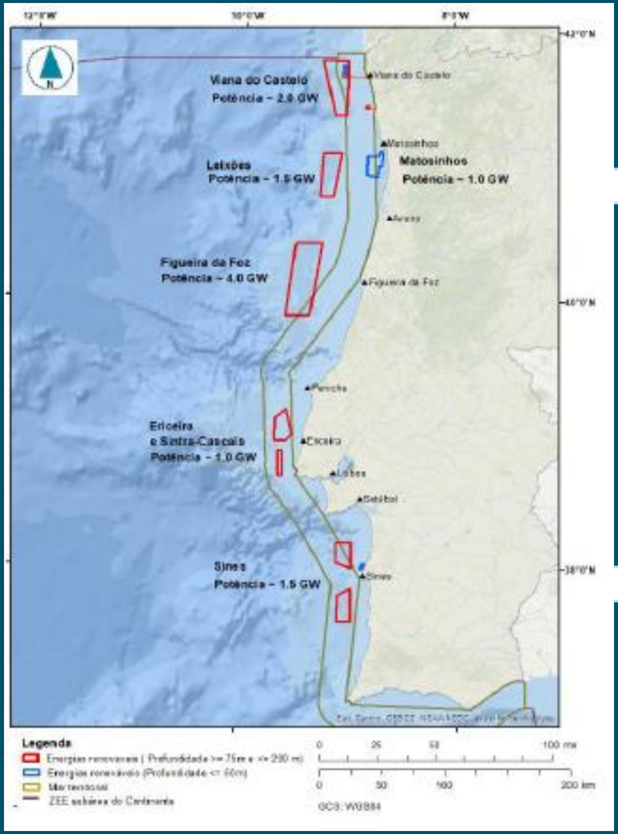
Evolution of Wind Offshore Installed Capacity

- Estimation of wind offshore installed capacity per Area (2040)



- Indicative values admitted for the wind offshore installed capacity in each area between 2030 – 2040:

Area	2030 (MW)	2035 (MW)	2040 (MW)
Viana	1500	2000	2000
Leixões	500	1500	1500
F. Foz	0	2500	4000
Ericeira & Sintra/Cascais	0	0	1000
Sines	0	0	1500
Total Capacity	**2000**	**6000**	**10000**

- Buses of interconnection with the RNT near to the wind offshore areas.

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Operational Scenarios Analysed

- Defined by crossing historical generation / load data gathered from ENTSO-E & REN for **representative scenarios with high/very high wind integration (≥ 70%)** and considering future projections for the load growth, generation installed capacity and for the commercial power exchanges between Portugal and Spain

- Scenarios simulated so far (the most critical)*:

Technology	2040 Admmited Installed Capacity (MW)*	2040 Wet Winter Peak Load Scenario (MW)	2040 Dry Summer Intermediate Load Scenario (MW)
Fossil Gas	0	0	0
Hydro Water Reservoir	1678	1091	0
Hydro Run-of-river and poundage	2517	1840	0
Hydro Pumped Storage	3593	2660	-3593
Small hydro (≤ 30 MW)	620	620	0
Wind onshore	12900	9030	8510
Wind offshore	10000	7000	7000
Solar (PV + CPV + CSP)	28681 (17374 MW assumed for H2)	0	5653
CHP + Biomass + Biogas	1373	900	900
Others	298	150	150
Total Generation	**61660**	**23291**	**18620**
Total Load**	–	**18112**	**14057**
Total Power Exchanges: (+) exp. from Portugal (-) imp. from Spain	**Max. Commercial Exp. – 4000** **Max. Commercial Imp. – 4700**	**4000**	**4000**

* based on RMSA Projections

** Admitting an additional load of 8 GW connected to Sines (400 kV)

WHILE there are overloads AND the maximum number of iterations is not reached

Oriented Grid Reinforcement Search Algorithm

IDENTIFY the most relevant contingencies using Line Outage Distribution Factors calculated for RNT's extreme operating scenarios

- Around 70 relevant contingencies were identified

IDENTIFY the 400 kV substations to be connected by double HVAC circuit with 2300 MVA or double HVDC circuit with 1200 MW and CALCULATE respective distances (only circuits of up to 300 km were considered)

Randomly CREATE the initial solution from up to 5 reinforcements and ADD the solution to a list of the top best 20 solutions

CALCULATE overloads in extreme operating scenarios considering the simulation of 70 relevant contingencies and DC modeling for the network

WHILE there are overloads AND the maximum number of iterations is not reached

- SELECT a solution from the list of top 20 solutions
- APPLY a small change to this solution randomly
- PERFORM local search to identify the optimum in the neighborhood
- ADD the local optimum to the list of top 20 reinforcements if it has less overload than the worst solution in the list

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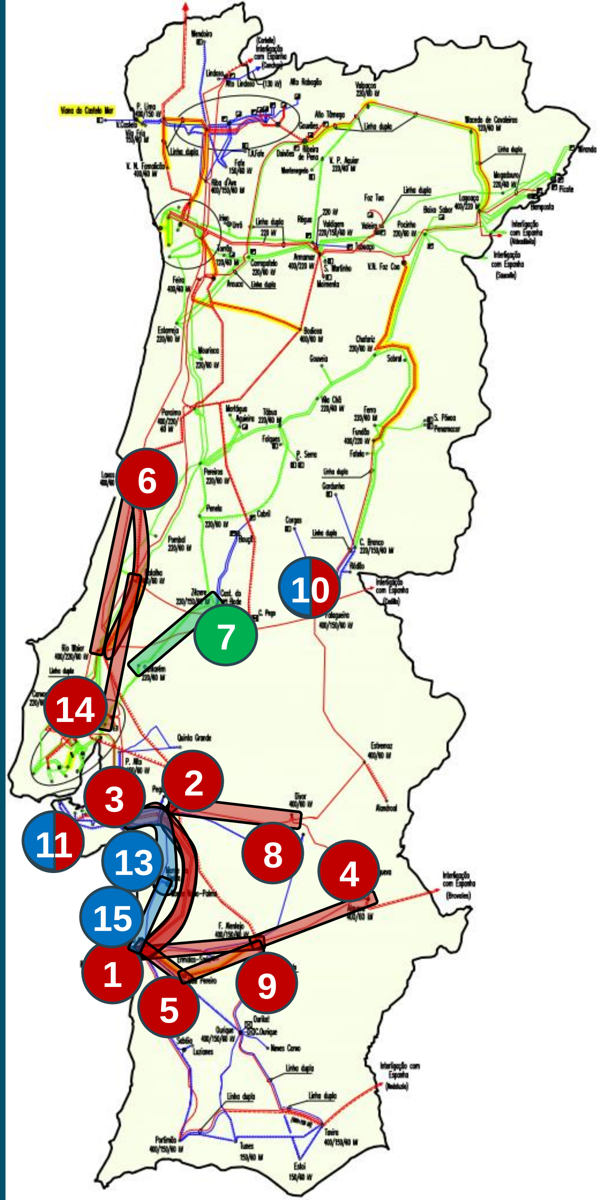
2040 Wet Winter Peak Load Scenario

	From	To	# Contingencies	Max. Overload
1	Ferreira do Alentejo	Sines	502	170.3
2	Sines	Pegões	504	151
3	Palmela	Sines	7	135.2
4	Ferreira do Alentejo	Alqueva	8	119.2
5	Sines	Vale Pereiro	2	117.7
6	R. Maior	Lavos	3	115
7	Zêzere	Santarém	2	114.9 (*)
8	Divor	Pegões	1	114.9
9	Ferreira do Alentejo	Vale Pereiro	2	112
10	Falagueira	Falagueira	2	111.1 (*)
11	Fernão Ferro	Fernão Ferro	1	110.8
12	Pocinho	Macedo de Cavaleiros	2	108.4 (**)
13	Palmela	Monte da Pedra	1	104
14	Batalha	Ribatejo	2	103.7
15	Sines	Monte da Pedra	1	103



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2040 Wet Winter Peak Load Scenario

- **Reinforcement – Alternative 1 (A1):**
  - **Sines – Lavos (258 km)**: 2 x 2372 MVA, **HVAC** (400 kV) **OR** 2 x 1200 MW, **HVDC**
  - **AND F. Alentejo – Sines (59 km)**: 1 x 1386 MVA, **HVAC** (400 kV)

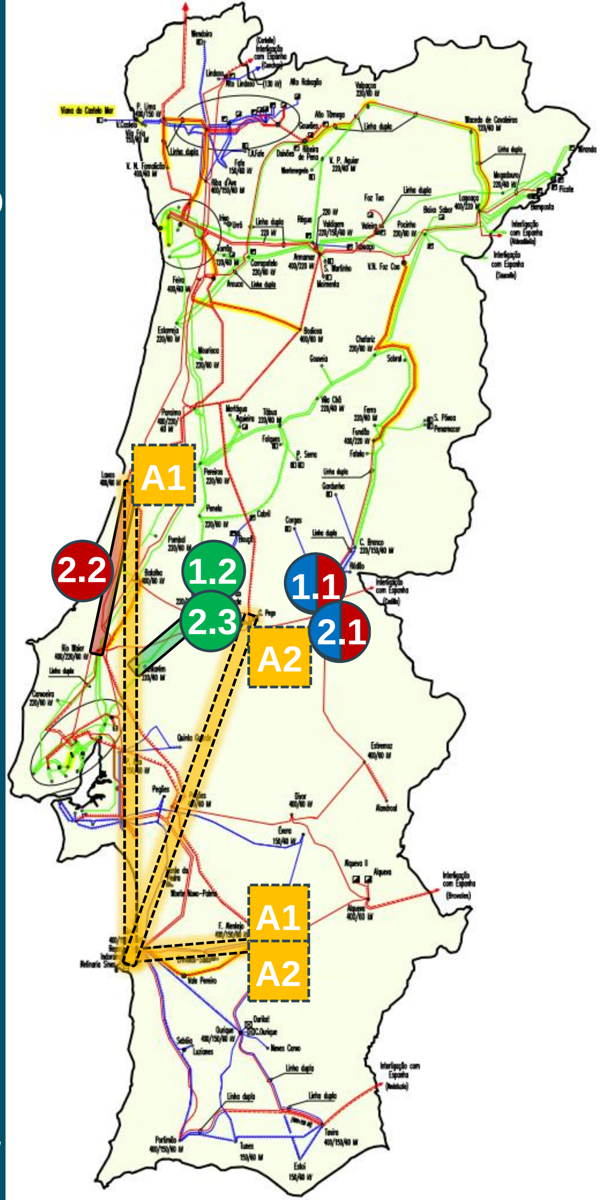
1.x	From	To	# Contingencies	Max. Overload
1	Falagueira	Falagueira	2	105.3 (*)
2	Zêzere	Santarém	2	103.5 (*)

  - *Considering Sines – Lavos as **HVDC** circuits, the overloads are similar, but their magnitudes are slightly lower*

- **Reinforcement – Alternative 2 (A2):**
  - **Sines – Pego (215 km)**: 2 x 2372 MVA, **HVAC** (400 kV) **OR** 2 x 1200 MW, **HVDC**
  - **AND F. Alentejo – Sines (59 km)**: 1 x 1386 MVA, **HVAC** (400 kV)

2.x	From	To	# Contingencies	Max. Overload
1	Falagueira	Falagueira	2	115.6 (*)
2	R. Maior	Lavos	1	104.5 (***)
3	Zêzere	Santarém	2	104.3 (*)
4	Pocinho	Macedo de Cavaleiros	1	103.4 (**)

  - *Considering Sines – Pego as **HVDC** circuits, the overloads are similar, but their magnitudes are slightly lower*



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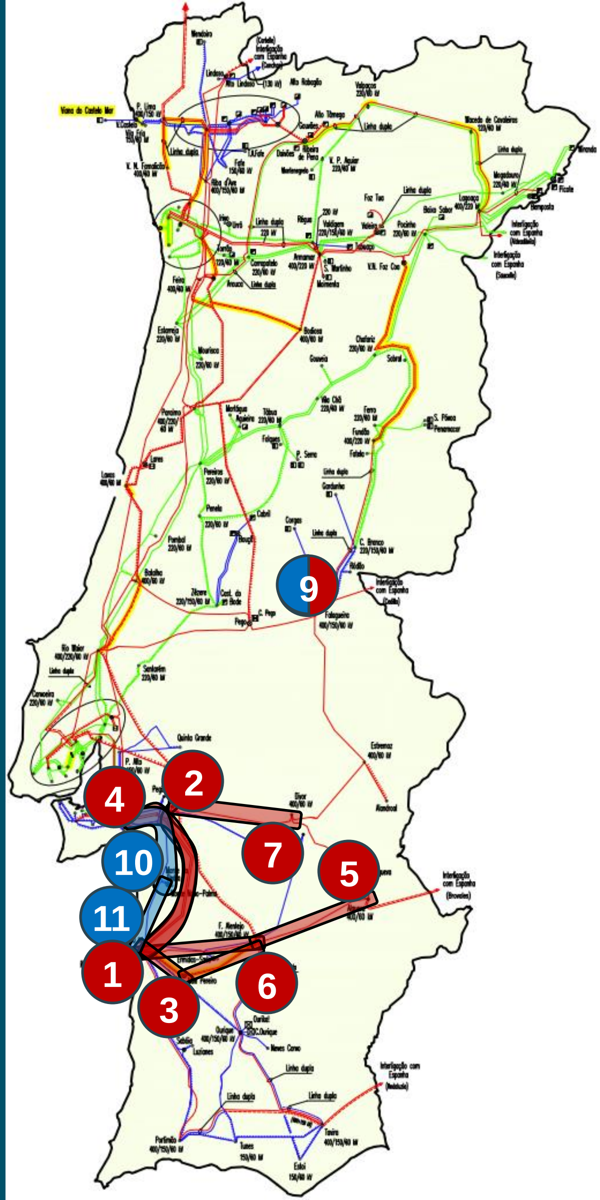
2040 Dry Summer Intermediate Load Scenario

	From	To	# Contingencies	Max. Overload
1	Ferreira do Alentejo	Sines	502	170.3
2	Sines	Pegões	504	150.4
3	Sines	Vale Pereiro	5	139.9
4	Palmela	Sines	7	134.7
5	Ferreira do Alentejo	Alqueva	8	122.5
6	Ferreira do Alentejo	Vale Pereiro	2	122.4
7	Divor	Pegões	1	108.8
8	Pocinho	Macedo de Cavaleiros	1	106.2 (**)
9	Falagueira	Falagueira	2	102.8 (*)
10	Palmela	Monte da Pedra	1	101.8
11	Sines	Monte da Pedra	1	101.2



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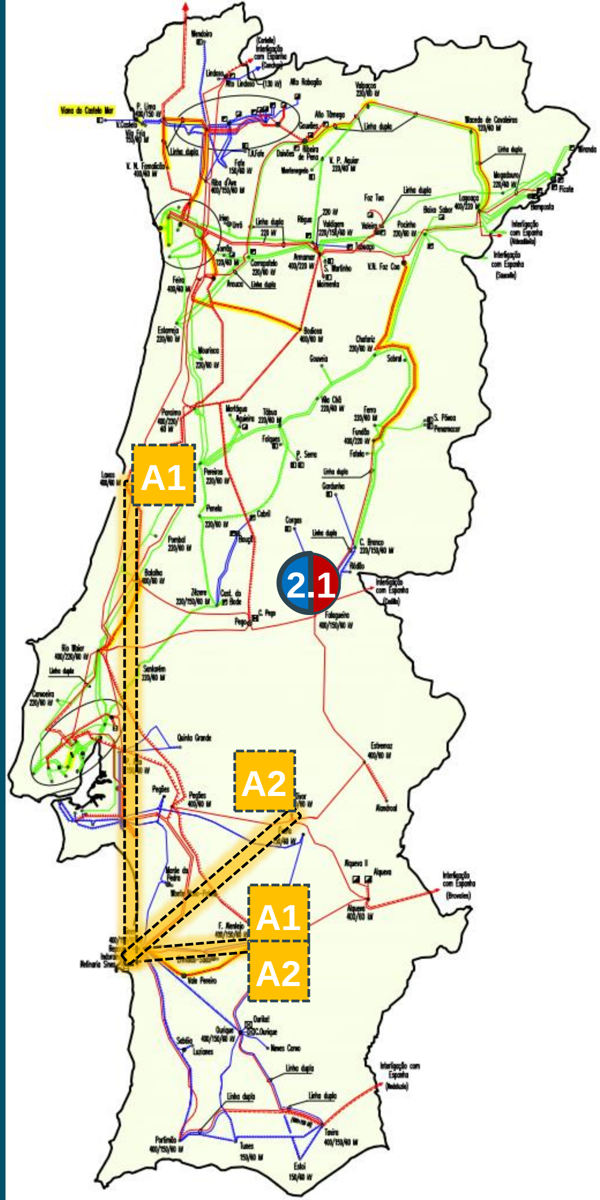
2040 Dry Summer Intermediate Load Scenario

- **Reinforcement – Alternative 1 (A1):**
  - **Sines – Lavos (258 km)**: 2 x 2372 MVA, **HVAC** (400 kV) **OR** 2 x 850 MW, **HVDC**
  - **AND F. Alentejo – Sines (59 km)**: 1 x 1386 MVA, **HVAC** (400 kV)

→ ***No overloads occurred*** *(considering Sines – Lavos either as **HVAC** or **HVDC**)*

- **Reinforcement – Alternative 2 (A2):**
  - **Sines – Divor (131 km)**: 2 x 2372 MVA, **HVAC** (400 kV)
  - **AND F. Alentejo – Sines (59 km)**: 1 x 1386 MVA, **HVAC** (400 kV)

2.x	From	To	# Contingencies	Max. Overload
1	Falagueira	Falagueira	2	105.1 (*)
2	Pocinho	Macedo de Cavaleiros	1	103.6 (**)



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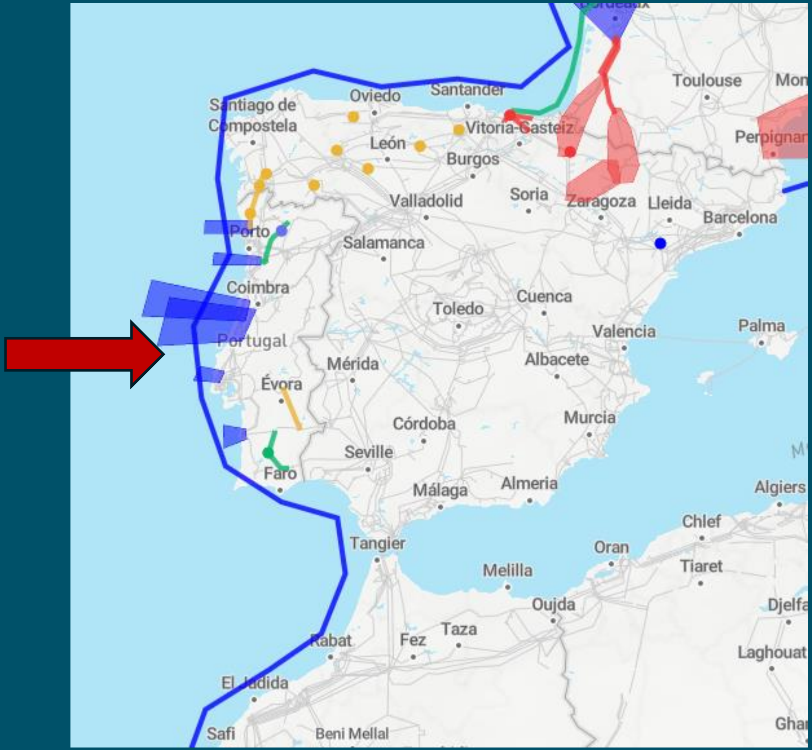
The HVDC solution framed by the TYNDP 2024

ENTSO-E published recently the TYNDP 2024 (Ten-year Network Development Plan) - TYNDP 2024 Project Collection (entsoe.eu).

- Developing hybrid interconnectors



Example: Beyond 2030 - A national blueprint for a decarbonized electricity system in Great Britain

Main Conclusions

- When operated in scenarios of large wind penetration (off-shore & on-shore), the grid will become stressed even in “Normal” operation conditions (if there is no RES curtailment). This situation is particularly critical for (n-1 and n-2) contingencies.
- The Portuguese transmission grid will then require further investments. Simulations have shown that this is likely to happen when wind offshore capacity will increase more than around 2,5 GW.
- Several different solutions are possible to overcome this problem, either in HVAC or HVDC. Simulation studies performed so far (over the critical scenarios analysed) have shown that the reinforcement alternatives (either in AC or DC) are able to solve the highest overloading violations.
- In order to avoid additional high investments/ reinforcements in lines or transformers, the remaining overloads (less than 115%) are likely be solved through a dynamic management of the system (temporary curtailment or grid reconfiguration).

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Obrigado!
Thank you!