Deliverable 2.1.2

Detailed Project Description

03 - DZES Algeria - Spain

EC DEVCO - GRANT CONTRACT: ENPI/2014/347-006

"Mediterranean Project"

Task 2 "Planning and development of the Euro-Mediterranean Electricity Reference Grid "

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1 Introduction

This document contains the studies on the project DZES in the context of the Mediterranean Master Plan of Interconnections. Project DZES consists of a new HVDC interconnection between Spain and Algeria (+1000 MW DC).

The document is structured as follows. Section 2 describes the new HVDC interconnection project project in detail and the different data sources. Section 3 presents the definition of the snapshots considered in the analysis and a brief description of the snapshot building process followed by the CON. Section 4 comprises the criteria for the security analysis. Section 5 describes the reinforcements considered and the main results of the security analysis. Section 6 presents the active power losses calculations for the snapshots and for the new HVDC link. Finally, Section 7 summarizes the investment costs required in the new HVDC link and outlines the Cost Benefit Analysis (CBA) for the project DZES.

2 Project description and data acquisition

The project DZES consists in a new interconnection between Algeria and Spain to be realized through an HVDC submarine cable. The HVDC interconnection will have a capacity of 1000MW and a total length of around 240km. The maximum depth for the installation of the undersea cable is 2000m.

This project is promoted by SONELGAZ and REE.

Project details							
Description	***Substation (from)***	***Substation (to)***	***GTC contribution (MW)***	***Present status***	***Expected commissioning date***	***Evolution***	***Evolution driver***
New HVAC interconnection	CARRIL2 (ES)	AIN FATAH (DZ)	1000	Long-term project	Post 2030	Updated study was promoted by Sonelgaz and	Increase the NTC in the Mediterranean countries and providing mutual benefits according the

between Spain and Algeria.						REE and performed within the Mediterranean project n°I of Med-TSO.	complementary characteristics of both countries and therefore best optimizing economic opportunities of energy exchange

Two configurations have been provided for the new HVDC interconnection:

1. Single HVDC circuit (single pole converter) of 1000MW between CARRIL2, which is a new substation of 400kV (Spain) connected to CARRIL 400kV substation through a 400kV OHL double circuit, and a substation located in Terga region that will be connected to 400kV/220 kV substation (AIN FATEH) through two 400kV OHL of 50km (Algeria).
2. HVDC link of 2 circuits (bipolar converter) of 500MW each between CARRIL2, which is a new substation of 400kV (Spain) connected to CARRIL 400kV substation through a 400kV OHL double circuit, and a substation located in Terga region that will be connected to 400kV/220 kV substation (AIN FATEH) through two 400kV OHL of 50km each (Algeria).

Configuration 2 was used in the Network Studies. This configuration was evaluated considering a single and double contingency of the two HVDC link circuits to simulate the impact of Configuration 1 as well.

The system defined for project DZES is described in the table and figure below.

Full models	Boundaries
Spain ES	France FR
Portugal PT	Tunisia TN
Morocco MA	
Algeria DZ	

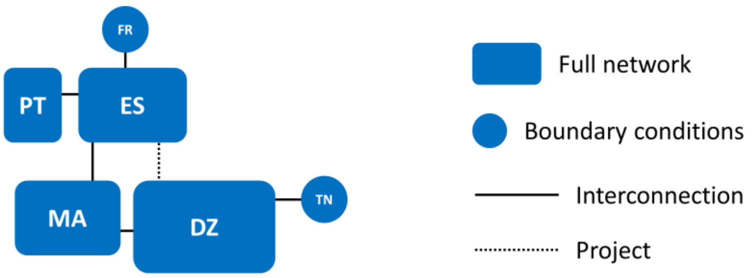

Table 1 – Participation of each of the electric systems involved in project DZES

In this project, the Portuguese, the Spanish, the Moroccan and the Algerian systems have been considered as represented by their full transmission network models. Boundary systems, i.e. France and Tunisia, were considered as external buses with equivalent loads to simulate energy interchanges.

Four scenarios (S1, S2, S3 and S4) and seasonality (Winter/Summer) are distinguished in the snapshots definition.

The following sections detail the different data supplied by the TSOs. The full list of files is included in [1].

Algeria

A set of eight models of the Algerian system have been provided plus an explanatory guideline for their format. Uploaded files are:

Name	Format	Notes
0.DZ_Database guidline&Market data_Common cases_S&W-Peak.xlsx	EXCEL	Guideline for the format used to collect network information
1.Database_2030_S1_Common case_Summer_Peak.xlsx	EXCEL	Network for S1, Summer
1.Database_2030_S1_Common case_Winter_Peak.xlsx	EXCEL	Network for S1, Winter
1.Database_2030_S2_Common case_Summer_Peak.xlsx	EXCEL	Network for S2, Summer

Name	Format	Notes
1.Database_2030_S2_Common case_Winter_Peak.xlsx	EXCEL	Network for S2, Winter
1.Database_2030_S3_Common case_Summer_Peak.xlsx	EXCEL	Network for S3, Summer
1.Database_2030_S3_Common case_Winter_Peak.xlsx	EXCEL	Network for S3, Winter
1.Database_2030_S4_Common case_Summer_Peak.xlsx	EXCEL	Network for S4, Summer
1.Database_2030_S4_Common case_Winter_Peak.xlsx	EXCEL	Network for S4, Winter

In the EXCEL files uploaded, generating technologies were identified using numbers. The following table identifies the technologies for Algerian generators:

Technologies identified in EXCEL	Med-TSO technologies
NUCLEAR	1 - NUCLEAR
CCGT - OLD	13 - GAS CCGT OLD 2 (45% - 52%)
CCGT - NEW	14 - GAS CCGT NEW (53% - 60%)
OCGT- OLD	17 - GAS OCGT OLD (35% - 38%)
WIND	26 - WIND ONSHORE
PV	23 - SOLAR PHOTOVOLTAIC
CSP	24 - SOLAR THERMAL
Hybrid	24 - SOLAR THERMAL
SVC (Static Var Compensator)	99-UNKNOWN
SLACK	Connection with Morocco (slack of the system)

Next table identifies the Algerian areas (4th character in bus code):

Area code in EXCEL networks	Area identified
1	Algerian system, area 1 of 7
2	Algerian system, area 2 of 7
3	Algerian system, area 3 of 7
4	Algerian system, area 4 of 7
5	Algerian system, area 5 of 7
6	Algerian system, area 6 of 7
7	Algerian system, area 7 of 7
M	Moroccan system
S	Algerian bus for project DZES
I	Algerian bus for project DZIT[1]
T	Tunisian system

Morocco

For the Moroccan system, two networks were provided in PSS/E .sav format. One of the networks corresponds to scenarios S1, S2 and S4, and the other to scenario S3. The two PSS/E .sav files are valid for Winter and Summer conditions. An EXCEL file was supplied with the merit order for generating units. Uploaded files are:

[1] Bus DZI**T**111 is renamed to ITA**I**111

Name	Format	Notes
Scenario_S1_v_1.SAV	PSS/ E v33	.sav file with the Moroccan network for S1, S2 and S4
Scenario_S3_v_1.SAV	PSS/ E v33	.sav file with the Moroccan network for S3
Merit_Order_v_1.XLSX	EXCEL	Merit order for generating units
carteDG 400 & 225 kV.PDF	PDF	Map of the Moroccan transmission grid

According to the information provided by ONEE, the transmission network in scenario S2 is equal to the network for scenario S1. The network for scenario S4 is also similar to the one for S1, except that there is an additional capacity of 2000MW from renewable projects:

- 1000MW PV is assumed to be developed through the distribution system and another equivalent capacity of 1000MW wind is expected to be located completely in the southern region of Morocco
- An HVDC-VSC link between the southern and the center regions of Morocco will be used to connect 1000MW wind to a new AC/DC substation in the region of BOUJDOUR, from which a 1050km HVDC-VSC link will be used to make the connection with the substation CHEMAIA

Generating technologies in the “Owner” field do not match with the standard Med-TSO nomenclature. Most of the technologies were identified directly from the merit order file but others have been redefined based on the category type in the merit order file to match the technologies in the PiT (Point in Time) as follows:

- Category 25 → Med-TSO Type 26
- Category 27 → Med-TSO Type 30
- Category 29 → Med-TSO Type 28

Only the units in the merit order list provided were considered to create the snapshots for the PiTs. Existing interconnections with Algeria and Spain are well defined.

It is important to highlight the process followed to build the different PiTs. The loads (except the ones with fixed load) were set proportionally to the load in the respective PSS/E .sav file until the total load in the PiT is met. Similar process was followed for the OTHER RES / NON RES production, taking into account the generation limits when available. The HYDRO, WIND and SOLAR dispatch were carried out according to the merit order and proportionally to the corresponding generation limits.

Portugal

The files provided for the Portuguese system had already been prepared considering the PiT files of the three projects involved in the Western Corridor. Thus, a set of nine models of the Portuguese system have been provided plus a map of the Portuguese transmission grid. Uploaded files are:

Name	Format	Notes
DZ-ES_case1_v_1.SAV	PSS/ E v33	.sav file with the Portuguese network project DZES, PiT 1
DZ-ES_case2_v_1.SAV	PSS/ E v33	.sav file with the Portuguese network project DZES, PiT 2
DZ-ES_case3_v_1.SAV	PSS/ E v33	.sav file with the Portuguese network project DZES, PiT 3
DZ-ES_case4_v_1.SAV	PSS/ E v33	.sav file with the Portuguese network project DZES, PiT 4
DZ-ES_case5_v_1.SAV	PSS/ E v33	.sav file with the Portuguese network project DZES, PiT 5
DZ-ES_case6_v_1.SAV	PSS/ E v33	.sav file with the Portuguese network project DZES, PiT 6
DZ-ES_case7_v_1.SAV	PSS/ E v33	.sav file with the Portuguese network project DZES, PiT 7
DZ-ES_case8_v_1.SAV	PSS/ E v33	.sav file with the Portuguese network project DZES, PiT 8
DZ-ES_case9_v_1.SAV	PSS/ E v33	.sav file with the Portuguese network project DZES, PiT 9
Portuguese transmission grid maps v_1.PDF	PDF	map of the Portuguese transmission grid

Interconnected areas were well identified. Generating technologies identified in the “Owner” field did not match with the standard Med-TSO nomenclature. Four PSS/E .idv files have been provided to convert the values in the “Owner” field to the ENTSO-E format, which was then converted to the Med-TSO format using a conversion table supplied by REN. The four .idv files are:

- Fuel Type TYNDP2016 V1.idv
- Fuel Type TYNDP2016 V2.idv
- Fuel Type TYNDP2016 V3.idv
- Fuel Type TYNDP2016 V4.idv

Spain

A set of six PSS/E .raw files of the Spanish system have been provided. The Spanish networks are not available in the Med-TSO database since these files have been provided to the CON directly via email. Uploaded files are:

Name	Format	Notes
2030_V1_PC06_ES.RAW	PSS/ E v33	.raw file with the Spanish network
2030_V1_PC09_ES.RAW	PSS/ E v33	.raw file with the Spanish network
2030_V1_PC10_ES.RAW	PSS/ E v33	.raw file with the Spanish network
2030_V4_PC02_ES.RAW	PSS/ E v33	.raw file with the Spanish network
2030_V4_PC04_ES.RAW	PSS/ E v33	.raw file with the Spanish network
2030_V4_PC08_ES.RAW	PSS/ E v33	.raw file with the Spanish network

It is important to highlight the process followed to build the different PiTs. The PSS/E .raw files were assigned to each PiT according with the minimum deviation between the demand, the generation and the interchanges in the PSS/E .raw files and the PiTs. Generating technologies identified in the “Owner” field did not match with standard Med-TSO nomenclature. An EXCEL file with a conversion table was provided by REE. Two merit order list for generating units were also provided: List Number 2 was used in studies of the interconnections MAES and DZES. The loads, except the ones with fixed value, were set proportionally to the loads in the PSS/E .raw file selected until the total load in the PiTs is met. Similar process was followed to set the production for the HYDRO, SOLAR, WIND and OTHER RES / NON RES, namely, by applying a proportional adjustment taking into account the corresponding generation limits.

3 Snapshots definition and building process

The project DZES considers a total number of 9 PiTs [2]. Each of the PiT contains the active power generated, the total load and the active power exported for each of the systems considered. All PiTs were evaluated in DC.

The following table shows the power balance for each of the PiTs in the project DZES:

	area	PG [MW]	PD [MW]	Pexport [MW]	13 MA	15 PT	17 ES	2 DZ	5 FR	19 TN
PiT1	13 MA	8762.9	9662.9	-900.0	0.0	0.0	-900.0	0.0	0.0	0.0
	15 PT	5509.9	7754.6	-2244.7	0.0	0.0	-2244.7	0.0	0.0	0.0
	17 ES	50504.2	52837.4	-2333.3	900.0	2244.7	0.0	1000.0	-6478.0	0.0
	2 DZ	32450.6	33150.6	-700.0	0.0	0.0	-1000.0	0.0	0.0	300.0
	5 FR	0.0	-6478.0	6478.0	0.0	0.0	6478.0	0.0	0.0	0.0
	19	0.0	300.0	-300.0	0.0	0.0	0.0	-300.0	0.0	0.0

	TN									
	area	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	6741.7	8441.3	-1699.7	0.0	0.0	-699.7	-1000.0	0.0	0.0
	15 PT	4883.6	7133.7	-2250.0	0.0	0.0	-2250.0	0.0	0.0	0.0
PiT2	17 ES	59574.7	51259.3	8315.5	699.7	2250.0	0.0	-1000.0	6365.8	0.0
	2 DZ	28983.0	26683.0	2300.0	1000.0	0.0	1000.0	0.0	0.0	300.0
	5 FR	0.0	6365.8	-6365.8	0.0	0.0	-6365.8	0.0	0.0	0.0
	19 TN	0.0	300.0	-300.0	0.0	0.0	0.0	-300.0	0.0	0.0
	area	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	8125.6	9785.1	-1659.5	0.0	0.0	-900.0	-759.5	0.0	0.0
	15 PT	5311.5	7627.6	-2316.1	0.0	0.0	-2316.1	0.0	0.0	0.0
PiT3	17 ES	44278.8	46634.1	-2355.3	900.0	2316.1	0.0	1000.0	-6571.5	0.0
	2 DZ	23354.5	23295.0	59.5	759.5	0.0	-1000.0	0.0	0.0	300.0
	5 FR	0.0	-6571.5	6571.5	0.0	0.0	6571.5	0.0	0.0	0.0
	19 TN	0.0	300.0	-300.0	0.0	0.0	0.0	-300.0	0.0	0.0
	area	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	7968.3	8892.6	-924.3	0.0	0.0	75.7	-1000.0	0.0	0.0
	15 PT	4285.8	7031.3	-2745.5	0.0	0.0	-2745.5	0.0	0.0	0.0
PiT4	17 ES	42807.3	44338.2	-1530.9	-75.7	2745.5	0.0	-1000.0	-3200.7	0.0
	2 DZ	24992.3	22692.3	2300.0	1000.0	0.0	1000.0	0.0	0.0	300.0
	5 FR	0.0	-3200.7	3200.7	0.0	0.0	3200.7	0.0	0.0	0.0
	19 TN	0.0	300.0	-300.0	0.0	0.0	0.0	-300.0	0.0	0.0
	area	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	6965.3	8865.3	-1900.0	0.0	0.0	-900.0	-1000.0	0.0	0.0
	15 PT	7061.5	7774.3	-712.9	0.0	0.0	-712.9	0.0	0.0	0.0
PiT5	17 ES	66474.8	55862.0	10612.8	900.0	712.9	0.0	1000.0	8000.0	0.0
	2 DZ	28970.8	28670.8	300.0	1000.0	0.0	-1000.0	0.0	0.0	300.0
	5 FR	0.0	8000.0	-8000.0	0.0	0.0	-8000.0	0.0	0.0	0.0
	19 TN	0.0	300.0	-300.0	0.0	0.0	0.0	-300.0	0.0	0.0
	area	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	7875.7	6456.6	1419.1	0.0	0.0	419.1	1000.0	0.0	0.0
PiT6	15 PT	5745.4	7287.2	-1541.8	0.0	0.0	-1541.8	0.0	0.0	0.0
	17 ES	47237.6	41350.5	5887.2	-419.1	1541.8	0.0	1000.0	3764.5	0.0
	2	24704.5	26404.5	-1700.0	-1000.0	0.0	-1000.0	0.0	0.0	300.0

	DZ									
	5 FR	0.0	3764.5	-3764.5	0.0	0.0	-3764.5	0.0	0.0	0.0
	19 TN	0.0	300.0	-300.0	0.0	0.0	0.0	-300.0	0.0	0.0
PiT7	**area**	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	7465.4	8365.4	-900.0	0.0	0.0	-900.0	0.0	0.0	0.0
	15 PT	4599.2	6751.9	-2152.7	0.0	0.0	-2152.7	0.0	0.0	0.0
	17 ES	50874.2	44024.9	6849.3	900.0	2152.7	0.0	1000.0	2796.7	0.0
	2 DZ	26135.5	26835.5	-700.0	0.0	0.0	-1000.0	0.0	0.0	300.0
	5 FR	0.0	2796.7	-2796.7	0.0	0.0	-2796.7	0.0	0.0	0.0
	19 TN	0.0	300.0	-300.0	0.0	0.0	0.0	-300.0	0.0	0.0
PiT8	**area**	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	7983.3	6383.3	1600.0	0.0	0.0	600.0	1000.0	0.0	0.0
	15 PT	5801.8	7791.1	-1989.2	0.0	0.0	-1989.2	0.0	0.0	0.0
	17 ES	52016.1	51586.4	429.7	-600.0	1989.2	0.0	-959.5	0.0	0.0
	2 DZ	30923.5	30664.0	259.5	-1000.0	0.0	959.5	0.0	0.0	300.0
	5 FR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	19 TN	0.0	300.0	-300.0	0.0	0.0	0.0	-300.0	0.0	0.0
PiT9	**area**	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	6408.65	6862.51	159.34	-453.87	0	0	-900.01	446.15	0
	15 PT	8698.72	8700.61	145.44	-1.89	0	0	-1.89	0	0
	17 ES	40460.64	29558.79	1562.69	10901.85	900.01	1.89	0	2000	7999.95
	2 DZ	15724.13	17870.27	330.1	-2146.15	-446.15	0	-2000	0	0
	5 FR	0	7999.95	0	-7999.95	0	0	-7999.95	0	0
	19 TN	0	300	0	-300	0	0	0	-300	0

Table 2 – Power balance for each of the PiTs defined in the project DZES

4 Power flow and security analysis

This section presents the criteria agreed to run the power flow and N-x security analysis for the snapshots built for the eight PiTs of the project DZES. Details on the methodology used for the security analysis are compiled in [3].

Algeria

For the Algerian system, the N-1 is focused on the transmission circuits. Therefore, the branches considered for the N-1 analysis are only those at 220kV and 400kV. Also, overloads are only checked for branches in 220kV and 400kV networks.

The EXCEL files considers three different values for the rates and tolerances, i.e. rateA, rateB and rateC. For lines, rateA is considered for Winter, rateB is considered for Summer, and rateC is unused. For transformers, rateA is considered as unique rate, thus rateB and rateC are unused.

The tolerance for overload is 0% for all branches, in N and N-1 situations.

No N-2 contingencies were defined for Algeria

Morocco

For the Moroccan system, the N-1 analysis is focused on the transmission network. Therefore, the N operation and the N-1 contingencies were considered assuming the rates of the lines equal to the nominal values in N operation and 120% in N-1 operation. In the case of the transformers, the nominal capacity was considered as maximum limit.

No N-2 contingencies were defined for Morocco.

Portugal

For the Portuguese system, N operation, N-1 contingencies, and N-2 contingencies (a detailed list with the circuits to which apply N-2 criteria was sent to the CON) have been considered.

The transmission lines limits are distinguished between Category A (t<20 min) and Category B (20 min<t<2 h). All lines of 400kV network, as well as the remaining lines that feed the "Large Lisboa area" and Setúbal peninsula, are included in the overload Category B, and therefore cannot be subject to temporary overloads. The following table summarizes the security criteria for the Portuguese network.

	Normal conditions	N-1	N-2
Lines[3] Category A (t<20min.) Category B (20min.<t<2h)	 0% 0%	 15% 0%	 15% 0%
Transformers Category A (t<20min.)	 0%	 25%(winter) 10%(summer) 15%(rest)	 25%(winter) 10%(summer) 15%(rest)
Category B (20min.<t<2h)	0%	20%(winter) 5%(summer) 10%(rest)	20%(winter) 5%(summer) 10%(rest

Table 3 – Thermal limits for the Portuguese system

Maximum angular differences have also been considered, namely, 25 degrees for 220kV and 150kV lines, and 30 degrees for 400kV lines and interconnections.

Spain

For the Spanish system, N operation, N-1 and N-2 contingencies (a detailed list with the circuits to which apply N-2 criteria was sent to the CON) were evaluated. Regarding thermal limits, the following table was applied.

	Normal conditions	N-1	N-2
Lines*	0%	15% in general but less than 20 minutes (0% in underground cables)	15%

Transformers	0%	0% in summer 10% in winter	10% in summer 20% in winter 15% in the remaining period

Table 4 – Thermal limits for the Spanish system

The reference bus for the merged network is VILLARIN 400 kV in Spain. The active power flows in the case of the PiTs evaluated in DC was multiplied by a factor of 1.11 to account for the reactive power flow contribution.

5 Assessment of reinforcements

Algeria

The Algeria system is affected by the project DZES mainly in 400kV network. An internal reinforcement was detected between NAAMA 400kV and TLEMCEN SUD 400kV substations. The following figure depicts the reinforcement required:

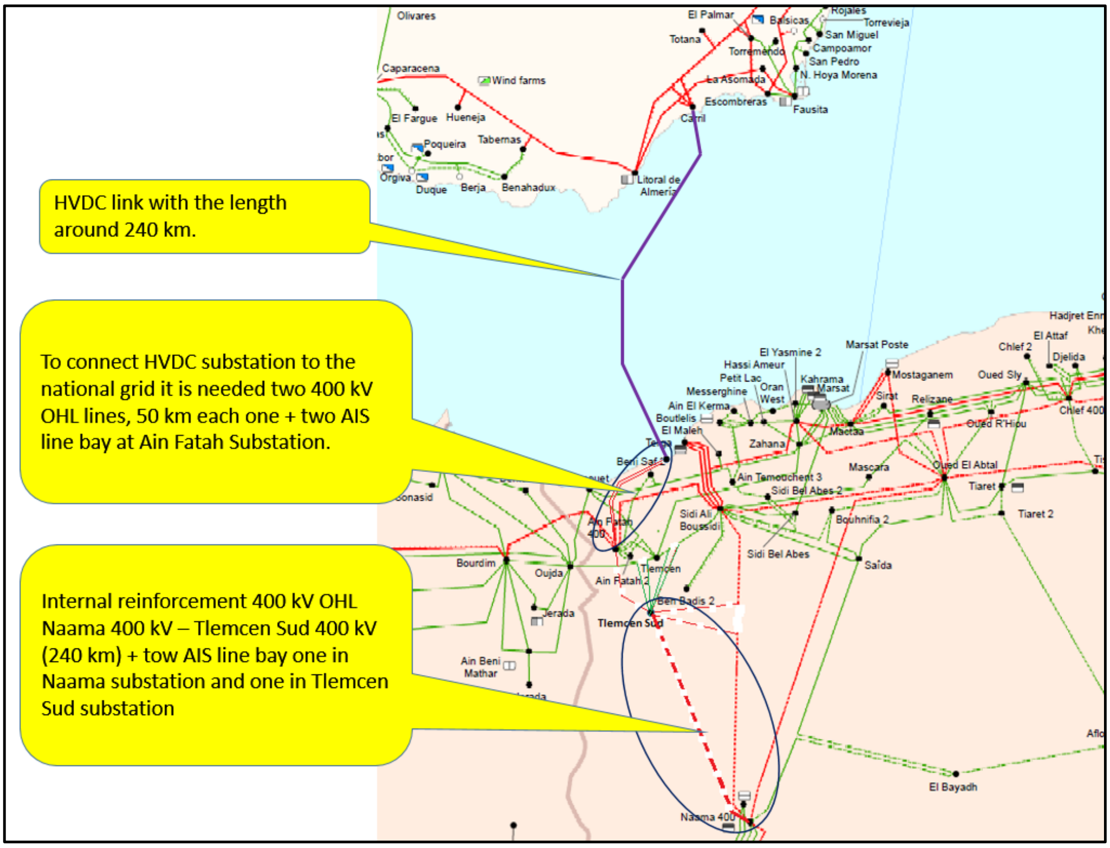

Figure 1 – Internal reinforcements in Algeria which were considered in order to accommodate the 1000 MW flow between Spain and Algeria (Med-TSO network studies)

Thus, the total cost for internal reinforcements in Algeria is **74.6M€.**

It is worth mentioning that the N-1 contingency of a 1000MW nuclear power plant in Algeria or the N-1 contingency of the new HVDC link in a symmetrical monopole configuration leads to significant overloads in the existing AC interconnection between Spain and Morocco. It is advisable to take action in order to mitigate the impact of such contingency without penalizing the transfer capabilities. Ad hoc studies should be performed to analyze the primary reserve capabilities of the area. To reduce costs of secondary reserves, interruptible loads integrated in special protection schemes could be designed to counteract the 1000MW nuclear plant trip.

Morocco

No significant overloads associated to the new DZES interconnection were identified in the Moroccan system, thus no reinforcements were defined for Morocco.

Spain

The Spanish system is affected by the project DZES in the 220kV and 400kV network. The new DC interconnection will depart from the new 400kV substation CARRIL2 which is connected to substation CARRIL via a double OHL of 10km. The following reinforcements were proposed and simulated:

- A rate upgrade of the 220kV OHL of 99 km between ATARFE - MAZUELOS - OLIVARES to 360MVA
- A new 400kV OHL of 38 km between TABERNAS - LITORAL de ALMERIA

This investments are 10 M€ for the rate upgrade of the 220kV OHL and 19M€ for the new 400kV OHL totaling 29M€.

The calculation have shown overloads in the Spanish grid also in N conditions. This suggested to investigate what part of the violations were due to the project DZES and which one was due to conditions independent of the project. Hence a "differential analysis" has been performed, i.e. the security assessment with the project DZES and without the project DZES. Redispatch of generation according to Market Studies was taken into account to obtain equivalent PiTs without the project DZES.

The simulations showed that without the project DZES several internal overloads in Spain appear. This is probably associated to the fairly high amount of solar generation expected in scenarios S2 and S4 in 2030. Some overloads also appeared in the tie lines FALAGEIRA-CEDILLO and ALQUEVA-BROVALES, between Portugal and Spain. In this context it is not advisable to perform detailed analysis to detect the optimal reinforcements made necessary by the project DZES, before planning a grid without overloads before simulating the project. This planning activity (when the RES penetration reaches 70%) requires time and should be approved in the national development plans. Besides this is out of the scope of the Mediterranean Master Plan which is focused on preliminary studies of planning and CBA evaluations.

Nevertheless, bearing in mind the abovementioned approximations and taking into account that the differential analysis has shown that some circuits have an evident increase in the overload with the project DZES of more than the 15%, and Table 5 shows the concrete reinforcements for the lines. Reconductoring interventions are also considered sufficient for the lines with an overflow less than 30% of the rate. The overloads of circuits with more than 30% of increase are assumed to be solved with an upgrade to a double line.

PiT	Bus From	V [kV]	Bus To	V [kV]	ID	Length [km]	Rate [MVA]	Max Loading w/ DZES [MVA]	Max Loading w/o DZES [MVA]	Difference [%]
2	CAMPOAMO	220	DESF.SMS	220	1	13.12	600	1264.64	1041.99	37.11
2	ASOMADA	400	CARRIL	400	1	78.64	880	956.26	685.3	30.79
1	GUADAME	220	OLIVARES	220	1	54.5	170	261.94	209.81	30.66
2	ELCHE2	220	SALADAS	220	1	5	530	1368.27	1223.95	27.23
2	PALMAR	400	ROCAMORA	400	1	78.45	1280	1842.22	1494.51	27.16
2	ROCAMORA	400	TREMENDO	400	1	26.3	1290	1904.1	1566.81	26.15
2	ROCAMORA	400	STA ANNA	400	1	38	1440	2714.66	2359.51	24.66
2	ELCHE2	220	ROJALES	220	1	24.68	590	1378.17	1233.85	24.46
2	ROJALES	220	SMSALINN	220	1	7.42	600	1540.54	1396.22	24.05

2	NESCOMBR	400	TREMENDO	400	1	41.3	1290	1423.99	1156.32	20.75
2	STA ANNA	400	SAX	400	1	46	1440	2004.49	1731.27	18.97
2	BENEJAMA	400	SAX	400	1	22.68	1480	2263.76	1994.2	18.21
4	PALMERAL	220	TORLLANO	220	1	14	506	510.56	419.74	17.95
2	CAMPOAMO	220	S.P.PINA	220	1	7.63	500	532.56	449.95	16.52
1	MINGLANI	400	OLMEDILL	400	1	46.7	990	1016.54	856.56	16.16
5	CABRA	400	MOLLINA	400	1	34	1240	1468.61	1268.65	16.13
5	CARTAMA	400	MOLLINA	400	1	52	1240	1454.19	1254.23	16.13
2	LA PLANA	400	GAUSSA	400	1	39.8	880	3437.09	3298.3	15.77

Table 5 – Circuits identified in Spain for reinforcement in order to accommodate the 1000MW flow between Algeria and Spain (Med-TSO network studies)

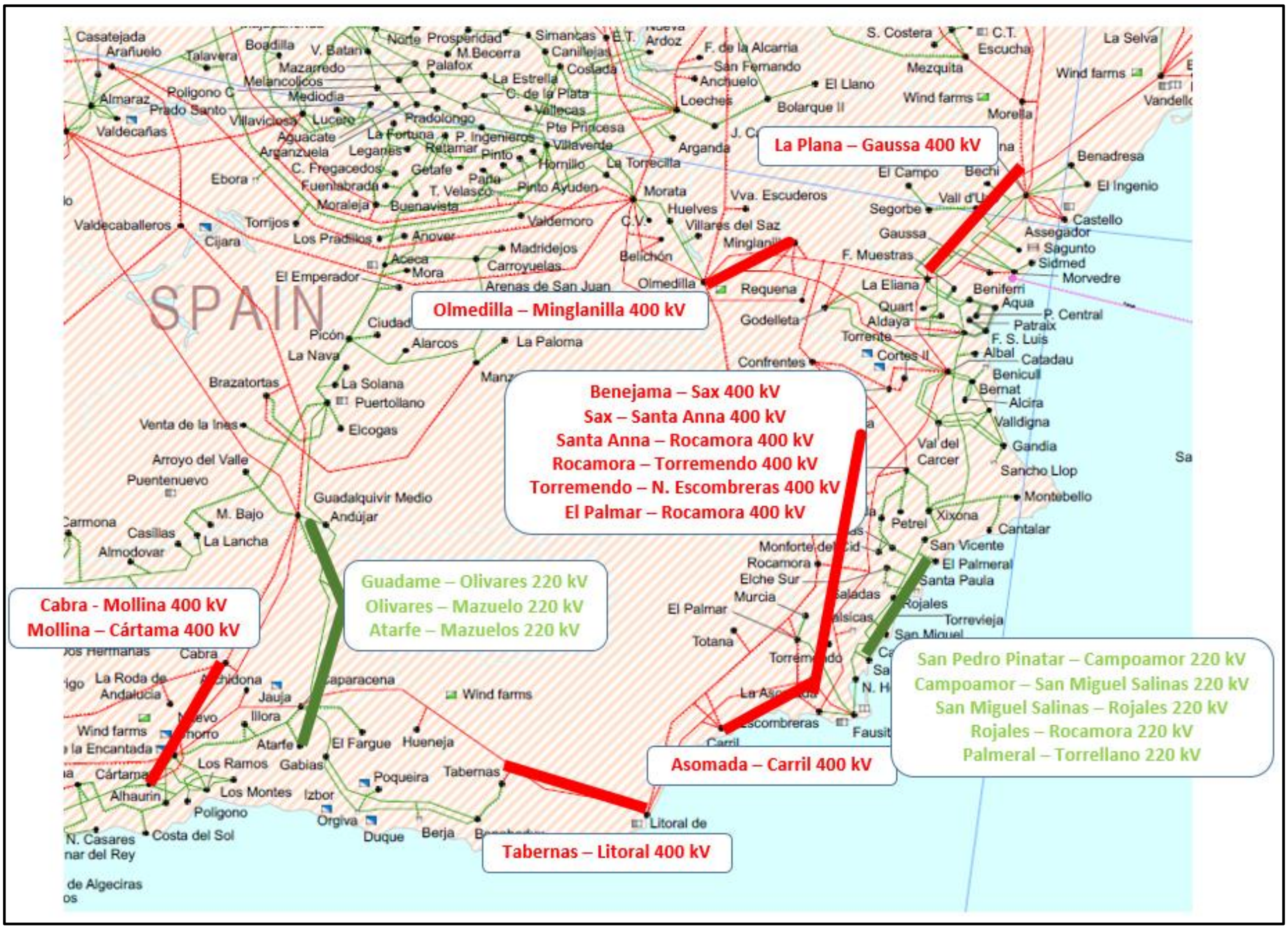

Figure 2 – Internal reinforcements in Spain which were considered in order to accommodate the 1000MW flow between Algeria and Spain (Med-TSO network studies)

The total investment cost for the reinforcements in Spain calculated with the above analysis is estimated to be 29M€ + 122M€ which amounts to **151M€**.

To complement the previous evaluations of concrete reinforcements for overload increases higher than 15% REE applied a different methodology to cover the overload increases between 5% and 15%, which implies also that overload increases lower than 5% are neglected. This methodology has lead to the identification of reinforcements needs equivalent to 63.443 MVA*km in 220 kV lines and 423.921 MVA*km in 400 kV lines. The estimates cost of this reinforcements needs if solved by uprating the overloaded lines is around 27M€.

Therefore, the estimate of the total internal reinforcement investment cost in Spain due to the project DZES is 29M€ + 122M€ + 27M€ = **178M€**.

For the purpose of the Mediterranean Master Plan it can be concluded that independent methodologies detected costs for internal reinforcements in Spain in the range of **151 M€-178M€.**

Portugal

No internal reinforcements due to the project DZES are envisaged in Portugal.

6 Estimation of active power losses

Internal losses in each country

To evaluate the performance of the interconnection project DZES plus the reinforcements identified, the active power losses have been computed for: a) the snapshots with the reinforcements identified; and b) the snapshots without the interconnection project DZES and without the reinforcements identified. The following tables show the active power losses for each PiT and system.

Algeria	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	453.3	492.7	39.4
2	537.9	565.0	27.1
3	306.2	384.1	77.9
4	339.7	403.0	63.3
5	462.1	426.4	-35.7
6	456.1	415.3	-40.8
7	479.5	356.2	-123.3
8	614.3	522.9	-91.4
9	281.0	197.5	-83.5

Table 6 – Comparison of the active power losses for each snapshot, with and without the interconnection project DZES and associated reinforcements, for the Algerian system

Morocco	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	340.5	332.3	-8.2
2	338.1	326.0	-12.1
3	426.7	413.5	-13.2
4	370.5	365.4	-5.1
5	376.5	372.4	-4.1
6	136.7	134.8	-1.9
7	348.4	339.1	-9.3
8	291.0	290.5	-0.5
9	166.3	163.0	-3.3

Table 7 – Comparison of the active power losses for each snapshot, with and without the interconnection project DZES and associated reinforcements, for the Moroccan system

Portugal	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	86.7	86.0	-0.7
2	245.4	248.1	2.7
3	78.2	78.1	-0.1

4	91.6	92.1	0.5
5	267.5	269.7	2.2
6	117.8	119.6	1.8
7	111.5	112.9	1.4
8	86	87.8	1.8
9	155.9	154.4	-1.5

Table 8 – Comparison of the active power losses for each snapshot, with and without the interconnection project DZES and associated reinforcements, for the Portuguese system

Spain	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	676.8	678.5	1.7
2	2663.6	2762.6	99.0
3	512.7	509.6	-3.1
4	484.2	506.2	22.0
5	3659.5	3575.6	-83.9
6	1013.9	964.5	-49.4
7	1085.9	1035.3	-50.6
8	876.2	931.1	54.9
9	1555.7	1491.9	-63.8

Table 9 – Comparison of the active power losses for each snapshot, with and without the interconnection project DZES and associated reinforcements, for the Spanish system

Losses in the new HVDC interconnection

Since the power system is weakly meshed between Spain and Algeria, it can be assumed that physical flows on the new interconnection circuits are similar to commercial exchanges. The calculation of the losses in the new HVDC interconnection was made for the four scenarios considering the bipolar HVDC-VSC technology with three different voltage levels: 320kV, 400kV and 500kV. The following table summarizes the results of the computations:

Scenario	Annual Losses (GWh)		
	320 kV	400 kV	500 kV
S1	373.12	239.54	195.38
S2	337.91	291.88	183.88
S3	234.45	212.29	179.35
S4	347.68	225.28	186.98

Table 10 – Annual losses estimate in the new HVDC-VSC link of the project DZES

7 Estimation of investment cost

Given the security analysis results, the new HVDC link between Algeria and Spain will have a bipolar configuration. The length of the DC cable is 240km. The following table provides an estimate for the investment cost in the new HVDC link based on the VSC technology. Note that this is a rough estimate based on similar projects that exist.

Technology		Costs			
	400kV AC OHL + Substation in Spain (M€)	400kV AC OHL + Substation in Algeria (M€)	Undersea Cable (M€/km)	Converters (M€)	Total (M€)
VSC Bipolar 2 x 500MW XPLE	11	32.6	1.41	270	652
VSC Bipolar	11	32.6	1.50	270	673.6

2 x 500MW MI					

Table 11 – Investment cost in the new DZES HVDC link

It is worth remarking the maximum depth of the HVDC connection is around 2000 m. Finally, the VSC technology has several advantages over the LCC technology that have not been directly quantified but should be taken into account, namely [4]:

- Active and reactive power can be controlled independently. The VSC is capable of generating leading or lagging reactive power, independently of the active power level. Each converter station can be used to provide voltage support to the local AC network while transmitting any level of active power, at no additional cost;
- If there is no transmission of active power, both converter stations operate as two independent static synchronous compensators (STATCOMs) to regulate local AC network voltages;
- The use of PWM with a switching frequency in the range of 1–2 kHz is sufficient to separate the fundamental voltage from the sidebands, and suppress the harmonic components around and beyond the switching frequency components. Harmonic filters are at higher frequencies and therefore have low size, losses and costs;
- Power flow can be reversed almost instantaneously without the need to reverse the DC voltage polarity (only DC current direction reverses).
- Good response to AC faults. The VSC converter actively controls the AC voltage/current, so the VSC-HVDC contribution to the AC fault current is limited to rated current or controlled to lower levels. The converter can remain in operation to provide voltage support to the AC networks during and after the AC disturbance;
- Black-start capability, which is the ability to start or restore power to a dead AC network (network without generation units). This feature eliminates the need for a startup generator in applications where space is critical or expensive, such as with offshore wind farms;
- VSC-HVDC can be configured to provide faster frequency or damping support to the AC networks through active power modulation;
- It is more suitable for paralleling on the DC side (developing multiterminal HVDC and DC grids) because of constant DC voltage polarity and better control.

A Cost Benefit Analysis (CBA) was carried out based on the results of EES and TC1 activities of the Mediterranean Project. The following tables summarizes the results obtained.

Rules for sign of Benefit Indicators		Assessment	Color Code
B1- Sew [M€/Year]	Positive when a project reduces the annual generation cost of the whole Power System	negative impact	(red)
B2-RES integration [GWh/Year]	Positive when a project reduces the amount of RES curtailment	neutral impact	(light peach)
B3-CO_2 [kt/Year]	Negative when a project reduces the whole quantity of CO_2 emitted in one year	positive impact	(green)
B4-Losses - [M€/Year] and [GWh/Year]	Negative when a project reduces the annual energy lost in the Transmission Network	not available/ not applicable	(grey)
B5a-SoS [MWh/Year]	Positive when a project reduces the risk of lack of supply	monetized	(yellow)

Assessment results for the Cluster P3 - DZES														
non scenario specific	GTC increase direction 1 (MW)		1000											
	GTC increase direction 2 (MW)		1000											
scenario specific			MedTSO scenario											
			1			**2**			**3**			**4**		
			Ref. Scenario	with new project	Delta	Ref. Scenario	with new project	Delta	Ref. Scenario	with new project	Delta	Ref. Scenario	with new project	Delta
GTC / NTC (import)		DZ	1300	2300	1000	1300	2300	1000	1300	2300	1000	1300	2300	1000
		ES	12100	13100	1000	12100	13100	1000	12100	13100	1000	12100	13100	1000
Interconnection Rate (%)*		DZ	2.6%	4.7%	2.0%	2.5%	4.3%	1.9%	1.9%	3.4%	1.5%	2.0%	3.6%	1.6%
		ES	9.5%	10.3%	0.8%	9.2%	9.9%	0.8%	8.2%	8.9%	0.7%	6.8%	7.4%	0.6%
Benefit Indicators	B1-SEW	(M€/y)	140			190			120			200		
	B2-RES	(GWh/y)	90			620			210			1100		
	B3-CO_2	(kT/y)	2400			-1000			1500			-1300		
	B4 - Losses**	(M€/y)	15.7			19.9			14.0			15.5		
		(GWh/y)	257			309			227			242		
	B5a-SoS Adequacy	(MWh/y)	0			0			40			20		
	B5b-SoS System Stability													
Residual Impact Indicators	S1- Environmental Impact													
	S2-Social Impact													
	S3-Other Impact													
Costs	C1-Estimated Costs***	(M€)	899-926											

* considering the GTC for 2030 , the Install generation for 2030 and the GTC for importation (the same criteria used in the ENTSO-E)

** Estimation of losses in the HVDC interconnection considered VSC technology (bipolar 400 kV)

*** Range for investment cost dependent on cost of internal reinforcements in the Spanish grid and selecting MI as cable technology

Table 12 – Cost Benefit Analysis for the project DZES

8 References

1	Snapshots building process	Share point
2	Guide for setting up grid models for Network studies V 5.0	Share point
3	Network Analysis and Reinforcement Assessment	Share point
4	D. Jovcic and K. Ahmed, “Introduction to DC Grids,” in High-Voltage Direct-Current Transmission, John Wiley & Sons, Ltd, 2015, pp. 301–306.	

ANNEX I

Maximum overload in Spain

PiT	Bus From	V [kV]	Bus To	V [kV]	CKT	rate [MVA]	load flow w/ proj [%]	load flow w/o proj [%]	max load flow w/ proj [%]	max load flow w/o proj [%]
2	ELEMPERA	220	MORA	220	1	170	327%	324%	415%	412%
2	ACECA	220	MORA	220	1	170	320%	318%	408%	405%
2	LA PLANA	400	GAUSSA	400	1	880	231%	222%	391%	375%
2	ELIANA	400	GODELLET	400	1	1500	230%	223%	317%	308%
2	ELIANA	400	GAUSSA	400	1	1370	180%	173%	288%	277%
2	ARAGON	400	MUDEJAR	400	1	840	155%	151%	284%	276%
2	ARAGON	400	MUDEJAR	400	2	840	155%	151%	284%	276%
8	TRUJILLO	220	MERIDA	220	1	180	172%	171%	276%	275%
2	CATADAU	400	TORRENTE	400	1	1500	128%	124%	269%	261%
2	LOECHES	400	MORATA	400	1	1460	197%	194%	261%	255%
2	ELIANA	400	LA PLANA	400	1	1370	151%	145%	259%	249%
2	ELIANA	220	PUZOL	220	1	430	118%	113%	258%	248%
2	ELCHE2	220	SALADAS	220	1	530	142%	125%	258%	231%
2	ROJALES	220	SMSALINN	220	1	600	154%	139%	257%	233%
2	ALBAL	220	CATADAU	220	1	330	156%	150%	255%	246%
2	MORVEDRE	220	SAGUNTO	220	1	430	142%	136%	253%	243%
2	MORVEDRE	220	PUZOL	220	1	430	106%	101%	247%	237%
2	ELIANA	400	TORRENTE	400	1	1500	100%	96%	246%	238%
2	ALBAL	220	TORRENTE	220	1	330	142%	136%	241%	232%
5	CARMONA	220	VNUEVREY	220	1	340	78%	78%	234%	231%
2	ELCHE2	220	ROJALES	220	1	590	129%	114%	234%	209%
9	ALMARAZ	220	TRUJILLO	220	1	180	139%	139%	233%	233%
2	MORATA	400	TVELASCO	400	1	780	98%	95%	231%	226%
2	AYORA	400	COFRENTE	400	1	1100	155%	146%	230%	216%
5	ALMODOVA	220	CASINPB	220	1	350	152%	149%	228%	224%
2	LA PLANA	400	CAMARLES	400	1	1380	113%	110%	224%	216%
2	VANDELLO	400	CAMARLES	400	1	1380	102%	99%	213%	205%
2	ALDAIA	220	TORRENTE	220	1	430	126%	122%	211%	204%
2	CAMPOAMO	220	DESF.SMS	220	1	600	96%	81%	211%	174%
2	ESCUCHA	220	HIJAR	220	1	210	115%	114%	205%	201%
2	ESCATROB	220	HIJAR	220	1	210	111%	109%	200%	197%
2	ESCATROB	220	MEQUINEN	220	1	230	105%	106%	200%	198%
5	LASELVA	220	AUBALS	220	1	410	134%	133%	195%	195%
2	ASCO	400	ESCATRON	400	1	840	130%	131%	192%	191%
5	MERIDA	220	VAGUADAS	220	1	250	109%	108%	192%	190%
2	GRADO	220	MONZON	220	1	210	85%	84%	189%	187%

2	ROCAMORA	400	STA ANNA	400	1	1440	127%	116%	189%	164%
5	ALVARADO	220	VAGUADAS	220	1	260	80%	79%	185%	182%
2	ET.LOEC1	400	LOECHES	400	1	1380	136%	132%	184%	179%
2	ET.LOEC1	400	ET.SSRR1	400	1	1380	136%	132%	184%	179%
2	SS REYES	400	ET.SSRR1	400	1	1380	136%	132%	184%	179%
2	GODELLET	220	TORRENTE	220	1	520	90%	88%	183%	178%
2	ALDAIA	220	QUARTPOB	220	1	430	96%	91%	181%	173%
2	MAGALLON	400	EJEACAB	400	1	1335	99%	98%	178%	176%
2	MAGALLON	400	EJEACAB	400	2	1340	101%	100%	178%	176%
8	MORALEJA	400	VILLAVIC	400	1	780	137%	133%	177%	172%
9	SALTERAS	220	GUILLENA	220	1	310	66%	68%	175%	172%
2	AYORA	400	CAMPANAR	400	1	1790	117%	114%	175%	168%
5	ESPARTAL	220	MONTETOR	220	1	260	71%	71%	173%	174%
2	FACINAS	220	PTO CRUZ	220	1	490	1%	0%	173%	173%
2	EL COTO	220	SIMANCAS	220	1	404	82%	80%	173%	170%
2	ELIANA	220	QUARTPOB	220	1	430	88%	83%	173%	165%
2	COFRENTE	400	LA MUELA	400	2	1170	96%	95%	172%	170%
2	COFRENTE	400	LA MUELA	400	1	1170	95%	94%	172%	170%
2	ALDEADAV	400	VILLARIN	400	1	1510	132%	130%	172%	170%
2	FALAGUE	400	CEDILLO	400	1	1300	125%	124%	171%	169%
2	MEDIODIA	220	MAZARRED	220	1	485	104%	102%	171%	169%
2	MEDIANO	220	P.SUERT	220	1	210	66%	65%	170%	169%
2	GARO-BAR	400	BUNIEL	400	1	950	128%	127%	169%	168%
2	PALMERAL	220	ALICANTE	220	1	417	123%	114%	169%	156%
2	DESF.SMS	220	SMSALINS	220	1	750	77%	64%	169%	139%
2	VANDELLO	400	CAPELLAD	400	1	930	130%	129%	169%	167%
2	MBECERRA	220	PROSPERI	220	1	240	66%	66%	168%	167%
2	ALDEADAV	220	VILLARIN	220	3	250	67%	66%	168%	165%
2	ALDEADAV	220	VILLARIN	220	4	250	67%	66%	168%	165%
2	CASACAMP	220	MAZARRED	220	1	462	96%	94%	166%	164%
2	MORATA	220	TORRECIL	220	1	490	82%	81%	166%	163%
5	CONSTANT	220	TARRAGON	220	1	320	86%	85%	165%	164%
3	GUILLE_B	220	CENT_NPB	220	1	170	105%	98%	164%	150%
2	ALMARAZ	400	GUADAME	400	1	690	102%	96%	162%	156%
2	BENEJAMA	220	JIJONA	220	2	360	70%	71%	162%	156%
2	BENEJAMA	220	JIJONA	220	1	360	70%	71%	161%	156%
2	CANTALAR	220	MTEBELLO	220	1	360	102%	96%	161%	153%
5	LASELVA	220	REUS II	220	1	310	83%	83%	161%	161%
2	COFRENTE	400	GODELLET	400	1	1500	91%	88%	160%	156%
2	ALDEADAV	400	ARANUELO	400	1	1280	122%	120%	160%	158%
2	MEDINACE	400	TRILLO	400	1	1310	116%	113%	159%	156%
2	JIJONA	220	VILLAJOY	220	1	360	95%	91%	159%	151%
2	MAGALLON	400	TERRER	400	1	1335	115%	113%	157%	154%
5	SABINANI	220	TESCALON	220	1	320	112%	111%	157%	156%
2	GRADO	220	MEDIANO	220	1	240	66%	65%	157%	156%

2	MEDINACE	400	RUEDA	400	1	1340	114%	112%	156%	154%
2	CEDILLO	400	JM.ORIOL	400	1	1280	110%	108%	156%	154%
2	MAGALLON	400	RUEDA	400	1	1335	113%	111%	156%	153%
2	CARROYUE	220	ARSNJUA	220	1	630	97%	95%	155%	154%
8	ELEMPERA	220	PICON	220	1	180	104%	100%	155%	149%
2	LA SERNA	220	TUDELA	220	2	320	41%	40%	154%	152%
1	GUADAME	220	OLIVARES	220	1	170	101%	74%	154%	123%
2	ROMICA	400	OLMEDILL	400	1	1320	99%	92%	154%	143%
2	ROMICA	400	OLMEDILL	400	2	1320	99%	92%	154%	143%
2	BENEJAMA	400	SAX	400	1	1480	106%	97%	153%	135%
2	ISONA	400	SENTMENA	400	1	730	94%	94%	153%	153%
9	ARGANDA	220	VALDMORO	220	1	350	105%	107%	152%	152%
5	MONTETOR	220	PLAZA	220	1	330	82%	81%	152%	152%
9	ACECA	220	CARROYUE	220	1	630	105%	107%	152%	152%
8	ALARCOS	220	MANZARES	220	1	180	46%	43%	151%	147%
2	ARAGON	400	VANDELLO	400	1	840	78%	78%	151%	149%
2	VITORIA	400	BRIVIESC	400	1	950	117%	117%	150%	149%
2	BENEJAMA	400	MONTESA	400	1	1340	109%	101%	150%	142%
2	PARRALEJ	220	GAZULES	220	1	305	5%	4%	150%	147%
2	CATADAU	400	MONTESA	400	1	1340	108%	100%	150%	141%
1	ESCATROB	220	ESPARTAL	220	1	240	83%	80%	150%	146%
3	SANTIPOB	220	CENT_NPB	220	1	350	116%	109%	149%	138%
2	GARO-BAR	400	LORA	400	1	990	103%	103%	149%	149%
5	LA POBLA	220	RUBIO	220	1	280	75%	74%	149%	149%
2	CRODRIGO	400	HINOJOSA	400	1	1280	119%	117%	149%	147%
2	CATADAU	400	GODELLET	400	1	1600	75%	70%	149%	141%
8	COSLADA	220	VILLAVER	220	1	315	83%	82%	148%	145%
2	CAMPONAC	220	EL COTO	220	1	433	63%	62%	148%	146%
2	ROCAMORA	400	TREMENDO	400	1	1290	40%	34%	148%	121%
2	GRIJOTA	400	BUNIEL	400	1	950	106%	105%	147%	145%
2	BESCANO	400	SENTMENA	400	1	2030	81%	81%	147%	147%
2	RIUDAREN	400	VIC	400	1	2030	66%	66%	147%	147%
2	CRODRIGO	400	ALMARAZ	400	1	1280	117%	115%	147%	145%
2	ALARCOS	220	PICON	220	1	320	24%	25%	146%	146%
2	CATADAU	400	LA MUELA	400	2	1170	95%	94%	145%	143%
2	PALENCIA	220	RENEDO	220	1	304	78%	78%	145%	143%
2	CATADAU	400	LA MUELA	400	1	1170	95%	94%	145%	143%
2	CANILLEJ	220	SIMANCAS	220	1	529	75%	74%	145%	143%
2	GURREA	220	ESQUEDAS	220	1	220	94%	93%	144%	144%
2	HERRERA	400	LORA	400	1	990	98%	97%	144%	143%
8	ELHORNIL	220	VILLAVER	220	1	415	77%	75%	144%	141%
2	MAJADAHO	220	VALLARCI	220	1	360	98%	97%	144%	143%
2	PALMAR	400	ROCAMORA	400	1	1280	93%	75%	144%	117%
2	PALMAR	400	ROCAMORA	400	2	1280	93%	75%	144%	117%
2	CANTALAR	220	ALICANTE	220	1	450	101%	92%	144%	131%

2	TERRER	400	TRILLO	400	1	1470	105%	103%	144%	141%
2	MTEBELLO	220	VILLAJOY	220	1	360	79%	75%	143%	135%
9	ALMODOVA	220	VNUEVREY	220	1	340	67%	64%	142%	140%
5	PSEVILLA	220	CENT_NPB	220	1	441	88%	82%	142%	134%
9	ALVARADO	220	MERIDA	220	1	260	84%	83%	142%	140%
2	ESCUCHA	220	VALDECON	220	1	300	79%	77%	141%	138%
2	GURREA	220	SABINANI	220	2	220	84%	84%	141%	141%
2	MUDARRA	400	TORDESIL	400	1	1360	113%	111%	141%	138%
8	ESCATROB	220	AUBALS	220	1	310	113%	113%	140%	140%
2	STA ANNA	400	SAX	400	1	1440	90%	81%	139%	120%
5	ALMARAZ	400	ARSERVAN	400	2	1760	92%	92%	139%	139%
2	GARO-BAR	400	GUENES	400	1	940	99%	98%	139%	138%
5	ABRERA	220	PUJALT	220	1	260	79%	78%	139%	138%
2	ALMARAZ	400	VILLAVIC	400	1	1280	109%	109%	138%	138%
2	ALMARAZ	400	VILLAVIC	400	2	1280	109%	109%	138%	138%
2	POLGORDO	400	LA ROBLA	400	1	820	88%	87%	138%	136%
2	GRIJOTA	400	BRIVIESC	400	1	950	105%	104%	138%	136%
2	ALDEADAV	400	HINOJOSA	400	1	1380	110%	109%	138%	136%
8	ACECA	220	PICON	220	1	320	103%	100%	138%	135%
2	JUNEDA	220	PERAFORT	220	1	280	87%	87%	137%	137%
8	ACECA	220	ANOVER	220	1	560	87%	86%	137%	135%
9	GUENES	220	TGUENES	220	1	360	84%	83%	137%	136%
2	GRIJOTA	400	HERRERA	400	1	1040	93%	91%	137%	135%
2	CATADAU	220	JIJONA	220	1	260	94%	86%	136%	125%
2	ALDEADAV	220	VILLARIN	220	1	330	54%	54%	136%	134%
2	ALDEADAV	220	VILLARIN	220	2	330	54%	54%	136%	134%
8	LUCERO	220	VILLAVIC	220	1	360	80%	79%	136%	134%
2	POLGORDO	400	SAMA	400	1	820	86%	84%	136%	134%
2	LA SERNA	220	TUDELA	220	1	290	36%	35%	135%	133%
5	S.CUGAT	220	C.JARDIB	220	1	240	98%	97%	135%	135%
8	PINTO	220	VILLAVER	220	1	350	61%	59%	135%	131%
2	BENEJAMA	220	CASTALLA	220	1	410	73%	68%	134%	125%
2	LA PLANA	400	MORELLA	400	2	1800	78%	75%	134%	127%
2	LA PLANA	400	MORELLA	400	3	1800	78%	75%	134%	127%
2	BESCANO	400	RIUDAREN	400	1	2030	53%	53%	134%	133%
5	ROMICA	400	MANZARES	400	1	1820	87%	85%	133%	130%
5	ROMICA	400	MANZARES	400	2	1820	87%	85%	133%	130%
2	HORTALEZ	220	PROSPERI	220	1	240	31%	30%	133%	132%
2	RUBI	400	MAIALS	400	1	820	94%	94%	132%	132%
2	CAMPANAR	400	PINILLA	400	1	1960	79%	76%	132%	125%
5	VIRGENRO	220	CENT_NPB	220	1	441	61%	58%	132%	125%
9	BASAURI	220	TGUENES	220	1	360	85%	85%	132%	132%
8	ACECA	220	PRADILLO	220	1	545	73%	71%	132%	130%
4	CENTELLE	220	SENTMENA	220	1	320	42%	41%	131%	128%
5	JUNDIZ	220	PUENTELA	220	1	539	95%	94%	130%	130%

8	LEGANES	220	LUCERO	220	1	280	58%	58%	130%	128%
5	CASINPB	220	AZAHARA	220	1	388	62%	61%	130%	127%
5	ALCORES	220	CARMONA	220	1	310	63%	60%	130%	126%
8	PINTO	220	TVELASCA	220	1	480	75%	74%	129%	127%
5	QUINTOS	220	S.ELVIRA	220	1	441	95%	93%	129%	125%
2	COMPOSTI	400	MONTEARE	400	1	900	69%	68%	128%	126%
8	MORATA	220	VILLAV B	220	1	350	86%	84%	128%	125%
5	RIBARROJ	220	ARNERO	220	1	210	36%	36%	128%	128%
5	GURREA	220	VILLANUE	220	1	207	42%	39%	128%	125%
3	TUDELA	220	MAGALLO2	220	1	330	58%	55%	128%	123%
5	PIEROLA	220	RUBIO	220	1	350	68%	67%	127%	127%
2	MEQUINEN	400	MAIALS	400	1	820	89%	88%	127%	126%
2	MIRASIER	220	VALLARCI	220	1	360	81%	80%	127%	125%
3	CARRIO	220	REBORIA	220	1	530	83%	82%	127%	126%
2	AYORA	400	COFRENTE	400	2	1100	44%	42%	127%	120%
5	GUILLENA	220	SANTIPON	220	4	350	57%	56%	126%	123%
5	GURREA	220	VILLANUE	220	2	210	41%	38%	126%	124%
5	LASOLANA	220	P.LLANO	220	1	320	4%	8%	125%	122%
5	CALDERS	400	SENTMENA	400	1	770	26%	26%	125%	125%
2	ALMARAZ	400	ALANGE	400	1	1430	72%	72%	125%	125%
9	AMOREBIE	400	ICHASO	400	1	940	60%	60%	125%	125%
5	BESCANO	400	LLOGAIA	400	1	2030	67%	67%	124%	124%
5	LLOGAIA	400	LAFARGA	400	1	2030	58%	58%	124%	124%
5	EALMARAZ	220	TORREJON	220	1	240	70%	70%	124%	124%
2	SAGUNTO	220	VALLDUXO	220	1	440	70%	68%	124%	120%
2	SABINANI	220	ESQUEDAS	220	1	220	74%	73%	124%	124%
2	AGUACATE	220	PQINGENI	220	1	470	76%	75%	124%	122%
5	DOSHMNAS	220	MIRABAL	220	1	350	59%	55%	124%	114%
8	EALMARAZ	220	CALERA	220	1	320	91%	91%	124%	124%
5	CASAQUEM	220	ONUBA	220	1	350	54%	54%	124%	123%
5	CASAQUEM	220	GUILLENA	220	1	350	70%	68%	124%	123%
2	GARRAF	400	VANDELLO	400	1	980	92%	91%	124%	122%
5	CARDIEL	220	MEQUINEN	220	1	210	46%	45%	124%	121%
2	ALANGE	400	BIENVENI	400	1	1430	70%	70%	123%	123%
5	EJEACAB	400	JACA	400	1	1800	61%	61%	123%	123%
5	EJEACAB	400	JACA	400	2	1800	61%	61%	123%	123%
2	FUENCARR	400	SS REYES	400	1	910	71%	69%	123%	120%
8	TALAVERA	220	CALERA	220	1	320	89%	89%	123%	123%
8	ASCO	400	ESPLUGA	400	1	940	80%	80%	122%	122%
5	SENGRACI	400	LA SERNA	400	1	840	63%	63%	122%	122%
8	PRADILLO	220	TVELASCA	220	1	545	63%	62%	122%	120%
5	ARCOSFRT	400	PINARREY	400	1	1260	84%	76%	122%	111%
5	SENGRACI	400	GARO-BAR	400	1	910	55%	55%	122%	123%
2	RUBI	400	DESVERN	400	1	1010	87%	86%	122%	121%
8	ET.CERR1	220	CERPLATA	220	1	420	66%	65%	122%	120%

8	ET.CERR1	220	VILLAVER	220	1	420	66%	65%	122%	120%
5	ALCORES	220	GIBALBIN	220	1	350	63%	58%	121%	111%
2	JALON	220	MAGALLON	220	1	370	28%	27%	121%	120%
2	JALON	220	MAGALLON	220	2	370	28%	27%	121%	120%
5	COFRENTE	400	MINGLANI	400	1	1310	54%	50%	121%	116%
5	GUILLENA	220	SANTIPOB	220	2	350	38%	35%	121%	116%
2	MUDEJAR	400	MORELLA	400	1	1800	72%	71%	121%	117%
2	MUDEJAR	400	MORELLA	400	2	1800	72%	71%	121%	117%
5	ESCATROB	220	VILLANUE	220	1	210	61%	60%	120%	119%
5	ESCATROB	220	VILLANUE	220	2	210	61%	60%	120%	119%
9	MINGLANI	400	REQUENA	400	1	1020	89%	87%	120%	119%
5	LA ROBLA	400	VILLAMEC	400	1	930	63%	63%	120%	121%
2	ESCATRON	400	FUENDETO	400	1	1480	73%	72%	120%	118%
5	PEREDA	220	SOTORIBE	220	1	250	100%	100%	120%	120%
5	LA PLANA	220	SERRALLO	220	1	320	70%	71%	119%	123%
4	TORRECIL	220	VILLAV B	220	1	420	62%	60%	119%	115%
1	PENAFLOR	400	EJEACAB	400	1	1340	83%	82%	119%	118%
5	CACERES	220	TORREJON	220	1	240	65%	64%	119%	118%
9	C.COLON	220	ONUBA	220	1	320	76%	75%	119%	117%
5	GATICA	400	GUENES	400	1	1590	93%	93%	119%	119%
5	CABRA	400	MOLLINA	400	1	1240	57%	46%	118%	102%
5	ICHASO	400	VITORIA	400	1	1030	89%	89%	118%	119%
2	NOVELDA	220	PETREL	220	1	410	60%	54%	118%	108%
2	RICOBAYO	220	VILLARIN	220	1	490	70%	69%	118%	116%
8	CERPLATA	220	PRINCESA	220	1	440	82%	80%	118%	115%
8	MEDIODIA	220	PRINCESA	220	1	370	75%	73%	118%	115%
2	GARO-BAR	400	ICHASO	400	1	1030	81%	81%	117%	117%
5	CARTAMA	400	MOLLINA	400	1	1240	56%	45%	117%	101%
5	QUINTOS	220	VIRGENRO	220	1	441	46%	43%	117%	109%
2	A.LEYVA	220	PQINGENI	220	1	510	69%	69%	117%	115%
8	ARANUELO	400	MORATA	400	1	720	88%	88%	117%	115%
8	ARANUELO	400	MORATA	400	2	720	88%	88%	117%	115%
5	JM.ORIOL	400	CANAVERA	400	1	1420	64%	65%	117%	117%
2	CANILLEJ	220	COSLADA	220	1	410	61%	60%	116%	115%
2	CANILLEJ	220	COSLADA	220	2	410	61%	60%	116%	115%
8	ANOVER	220	TVELASCA	220	1	630	71%	70%	116%	114%
2	RAMBLETA	220	VALLDUXO	220	1	500	59%	57%	115%	111%
4	PQINGENI	220	VILLAV B	220	2	400	66%	64%	115%	112%
3	MANFIGUE	220	PALAU	220	1	260	43%	43%	115%	115%
5	BEGUES	400	VILADECA	400	1	1010	59%	60%	115%	115%
1	LA POBLA	220	TSESUE	220	1	320	83%	82%	115%	112%
5	EALMARAZ	220	EBORA	220	1	400	84%	84%	115%	114%
8	ET.CERR2	220	CERPLATA	220	1	450	64%	63%	114%	113%
8	ET.CERR2	220	VILLAVER	220	1	450	64%	63%	114%	113%
2	TABIELLA	220	GOZON	220	2	530	64%	64%	114%	114%

2	GRIJOTA	400	MUDARRA	400	1	910	73%	71%	114%	112%
5	ARAGON	400	PENALBA	400	1	1300	77%	78%	114%	115%
2	AGUACATE	220	POLIGONC	220	1	470	66%	65%	114%	112%
1	ARAGON	400	PENAFLOR	400	1	1340	81%	79%	114%	112%
5	ISONA	400	PENALBA	400	1	1490	82%	82%	114%	114%
5	LLAVORSI	220	LA POBLA	220	1	410	87%	88%	114%	114%
5	COMPOSTI	400	VILLAMEC	400	1	900	54%	54%	113%	115%
3	REBORIA	220	GOZON	220	1	530	73%	73%	113%	113%
2	PRADSANT	220	RETAMAR	220	1	280	21%	21%	113%	112%
5	LASELVA	220	REUS II	220	2	441	58%	58%	113%	113%
2	TAVIRA	400	PUEGUZMA	400	1	1386	77%	76%	113%	111%
2	ARAGON	400	N.MEQUIN	400	1	1310	66%	65%	113%	111%
4	PQINGENI	220	VILLAV B	220	1	400	56%	55%	113%	110%
9	ASCO	400	PIEROLA	400	1	940	68%	68%	113%	113%
1	VIENTOS	220	MARIA	220	1	370	55%	54%	113%	111%
1	VIENTOS	220	MARIA	220	2	370	55%	54%	113%	111%
2	RUBI	400	VANDELLO	400	1	930	84%	83%	112%	111%
2	MUDARRA	400	SS REYES	400	1	910	83%	81%	112%	109%
2	PIEROLA	400	CAPELLAD	400	1	930	32%	31%	112%	111%
4	CENTELLE	220	CERCS	220	1	330	27%	26%	112%	110%
2	SAGUNTO	220	VALLDUXO	220	2	500	64%	61%	112%	108%
1	SALTERAS	220	SANTIPOB	220	1	350	95%	91%	112%	108%
8	TVELASCA	220	PINTOAYU	220	1	560	62%	61%	112%	110%
5	ANCHUELO	400	LOECHES	400	1	1460	44%	43%	112%	114%
5	CTCOMPOS	220	VILLABLI	220	1	250	92%	93%	112%	112%
8	ALMARAZ	220	EALMARAZ	220	1	350	50%	49%	112%	111%
2	PRADSANT	220	VILLAV_B	220	1	360	40%	40%	112%	111%
5	QUINTOS	220	DRODRI_B	220	1	170	15%	19%	111%	112%
5	BIENVENI	400	BROVALES	400	1	1270	43%	44%	111%	111%
5	ABRERA	220	RUBI	220	1	260	51%	50%	111%	110%
9	ALMARAZ	400	VILLAMIE	400	1	720	71%	70%	111%	110%
2	MUDARRA	400	LUENGOS	400	1	820	84%	83%	111%	109%
5	VALLEJER	220	VILLALBI	220	1	510	72%	73%	111%	111%
5	VILLALBI	220	VILLATOR	220	1	304	88%	87%	111%	110%
3	CARRIO	220	TABIELLA	220	2	530	47%	47%	111%	110%
2	LA ROBLA	400	MUDARRA	400	1	820	84%	82%	110%	108%
5	CARTUJA	220	DRODRI_B	220	1	350	45%	40%	111%	100%
2	NESCOMBR	400	TREMENDO	400	1	1290	33%	27%	110%	90%
2	LA ROBLA	400	LUENGOS	400	1	820	83%	82%	110%	108%
1	ESCALONA	220	TESCALON	220	1	320	78%	77%	110%	108%
1	ESCALONA	220	TSESUE	220	1	320	78%	77%	110%	108%
8	TVELASCO	400	VILLAVIC	400	1	780	35%	32%	110%	107%
8	C.JARDIB	220	CODONYER	220	1	240	63%	63%	109%	109%
5	TELLEDO	220	VILLABLI	220	1	250	89%	90%	109%	110%
2	MORALEJA	400	S.FERNAN	400	1	780	60%	60%	109%	109%

8	ELHORNIL	220	PINTOAYU	220	1	560	59%	58%	109%	107%
2	LA SERNA	400	EJEACAB	400	1	1335	56%	54%	109%	106%
5	ANOIA	220	ISONA	220	1	260	47%	47%	109%	109%
5	ISONA	400	ARNERO	400	1	1490	75%	76%	109%	109%
2	CARTUJOS	220	MONTETOR	220	1	360	71%	71%	109%	109%
2	VILLALCA	220	VILLARIN	220	1	304	75%	73%	109%	107%
2	VILLALCA	220	VILLARIN	220	2	304	75%	73%	109%	107%
2	ASOMADA	400	CARRIL	400	1	880	76%	54%	109%	78%
2	RAMBLETA	220	ASSEGADO	220	1	510	53%	51%	109%	104%
5	VILLALBI	220	VILLIMAR	220	1	360	71%	71%	108%	109%
2	LA ROBLA	400	SOTORIBE	400	1	1080	69%	67%	109%	107%
8	ARANUELO	400	VALDECAB	400	1	1280	69%	67%	108%	105%
8	ARANUELO	400	VALDECAB	400	2	1280	69%	67%	108%	105%
5	HOSPTLET	220	VILADECA	220	1	260	54%	54%	108%	108%
5	HOSPTLET	220	VILADECA	220	2	260	54%	54%	108%	108%
9	ACECA	220	VALDMORO	220	1	560	79%	80%	108%	108%
5	ALMARAZ	400	MORATA	400	2	1280	69%	69%	108%	108%
5	MORATA	400	VILLAMIE	400	1	1280	69%	69%	108%	108%
5	TORSEGRE	220	MEQUINEN	220	1	600	71%	71%	107%	107%
2	MUDARRIT	220	TMUDI2	220	2	360	55%	55%	107%	106%
2	PIEROLA	400	SENTMENA	400	1	960	42%	42%	107%	107%
8	CALDERS	400	ISONA	400	1	730	77%	77%	107%	107%
2	GALAPAGA	220	V.BATAN	220	1	280	55%	52%	107%	104%
5	GUILLENA	400	VALDECAB	400	1	700	46%	46%	107%	107%
7	GODELLET	400	REQUENA	400	1	910	81%	78%	107%	105%
2	PALMERAL	220	S.VICENT	220	1	506	50%	46%	107%	98%
5	VNESCUDE	400	TRILLO	400	1	1800	76%	78%	107%	111%
8	CARDIEL	220	ARNERO	220	1	210	34%	35%	107%	106%
2	CAMPOAMO	220	S.P.PINA	220	1	500	64%	55%	107%	90%
5	NOVELDA	220	SALADAS	220	1	450	46%	52%	106%	115%
5	NOVELDA	220	SALADAS	220	2	450	46%	52%	106%	115%
2	CANTALAR	220	JIJONA	220	1	360	13%	8%	106%	102%
5	OLMEDILL	400	TRILLO	400	1	1800	73%	76%	106%	110%
5	COSLADA	220	LOECHES	220	1	360	23%	23%	106%	107%
2	ARAGON	400	ARNERO	400	1	1300	78%	77%	106%	105%
5	C.COLON	220	TORARENI	220	2	170	55%	54%	106%	104%
2	MEQUINEN	400	N.MEQUIN	400	1	1310	59%	58%	106%	105%
1	PENAFLOR	220	VILLANUE	220	1	280	23%	25%	106%	106%
5	ALBATARR	220	TORSEGRE	220	1	600	70%	70%	106%	106%
5	PARRALEJ	220	PTO REAL	220	1	600	26%	24%	106%	105%
2	BESCANO	400	LAFARGA	400	1	2030	58%	58%	106%	106%
5	SIERO	220	SOTORIBE	220	1	470	80%	80%	106%	106%
2	MAJADAHO	220	TALAVERA	220	1	410	79%	79%	106%	106%
2	ALQUEVA	400	BROVALES	400	1	1280	62%	61%	106%	104%
8	PC_FAVE2	220	S.CUGAT	220	1	240	48%	48%	105%	105%

5	LA PLANA	220	ASSEGADO	220	1	500	47%	48%	105%	109%
5	LA PLANA	220	ASSEGADO	220	2	500	47%	48%	105%	109%
5	BENIFERR	220	TORRENTE	220	1	460	57%	58%	105%	107%
5	MARIA	220	MONTETOR	220	1	410	47%	48%	105%	106%
5	MARIA	220	MONTETOR	220	2	410	47%	48%	105%	106%
5	VILADECA	400	DESVERN	400	1	1010	30%	30%	105%	105%
8	ASCO	400	SENTMENA	400	1	940	67%	67%	105%	105%
8	ASCO	400	SENTMENA	400	2	940	67%	67%	105%	105%
2	HUELVES	220	MORATA	220	1	360	61%	58%	105%	99%
9	ARGANDA	220	LOECHESB	220	1	440	67%	68%	105%	105%
2	ARSNJUA	220	MANZARES	220	1	630	47%	44%	105%	104%
2	AGUAYO	400	VELILLA	400	1	930	82%	81%	105%	104%
8	CASACAMP	220	MBECERRA	220	1	240	43%	43%	104%	103%
2	GRIJOTA	400	VILLARIN	400	2	910	81%	80%	104%	103%
5	LASOLANA	220	PICON	220	1	320	45%	48%	104%	107%
5	AVEZARAG	220	PENAFLOR	220	1	360	36%	36%	104%	104%
2	HUELVES	220	VILLARES	220	1	360	61%	57%	104%	99%
5	PICON	220	P.LLANO	220	1	320	40%	44%	104%	107%
4	A.ZINC	220	TABIELLA	220	1	320	52%	52%	104%	104%
4	A.ZINC	220	TABIELLA	220	2	320	52%	52%	104%	104%
2	CASACAMP	220	NORTE	220	2	499	66%	66%	104%	103%
5	P.G.RODR	400	XOVE	400	2	1100	71%	72%	103%	103%
2	OLMEDILL	220	VILLARES	220	1	360	60%	56%	103%	97%
5	BSONUEVO	220	GRAMANTA	220	1	414	67%	67%	103%	103%
5	LANCHA	220	AZAHARA	220	1	388	35%	33%	103%	100%
2	CARMONIT	400	ARSERVAN	400	1	1470	68%	68%	103%	103%
1	MINGLANI	400	OLMEDILL	400	1	990	58%	55%	103%	87%
2	GRIJOTA	400	VILLARIN	400	1	910	78%	78%	102%	101%
9	BEGUES	400	ESPLUGA	400	1	940	64%	63%	102%	102%
5	MANFIGUE	220	C.JARDIB	220	1	240	49%	49%	102%	102%
2	PETREL	220	ELDA	220	1	410	45%	39%	102%	92%
5	OLIVARES	220	MAZUELOS	220	1	360	62%	47%	102%	86%
2	PALENCIA	220	TMUDI2	220	1	540	75%	74%	102%	101%
3	CANYET	220	GRAMANTB	220	1	350	46%	46%	102%	102%
5	AYORA	400	BENEJAMA	400	1	1100	10%	17%	102%	113%
5	ALVARADO	220	BALBOA	220	1	305	51%	49%	102%	100%
4	TARRAGON	220	REUS II	220	1	374	72%	72%	102%	101%
5	TABIELLA	220	GOZON	220	1	636	57%	57%	101%	102%
5	PIEROLA	220	C.JARDIB	220	1	550	84%	84%	101%	101%
2	BEGUES	400	GARRAF	400	1	1010	71%	70%	101%	100%
5	ICHASO	220	ELGE_NP	220	1	320	30%	30%	101%	101%
5	CAMPONAC	220	HORTALEZ	220	1	440	18%	19%	101%	103%
2	ESCATROA	220	ESCATROB	220	1	600	51%	50%	101%	101%
9	GATICA	220	GUENES_B	220	2	360	49%	49%	101%	101%
2	LA ESTRE	220	MORATA	220	1	470	68%	67%	101%	99%

2	PENARRUB	400	PINILLA	400	1	1470	66%	54%	101%	86%
4	PALMERAL	220	TORLLANO	220	1	506	79%	66%	101%	83%
5	ALBATARR	220	MANGRANE	220	1	600	65%	65%	101%	101%
2	GRADO	400	GOZON	400	1	1090	57%	57%	101%	100%
2	A.LEYVA	220	ARGANZUE	220	1	520	54%	53%	101%	99%
1	S.ANDREU	220	TRINITAT	220	1	414	61%	61%	101%	101%
5	PALENCIA	220	VILLALBI	220	1	550	63%	63%	101%	101%
2	COSLADAB	220	LOECHESB	220	1	360	70%	69%	100%	99%
5	ADRALL	220	LLAVORSI	220	1	410	74%	74%	100%	100%
5	TORRIJOS	220	TVELASCB	220	1	320	62%	62%	100%	100%
2	LA ESTRE	220	ARDOZ	220	1	450	50%	48%	100%	98%
5	ANCHUELO	400	TRILLO	400	1	1470	21%	19%	100%	102%
9	ALMARAZ	400	CARMONIT	400	1	1470	73%	73%	100%	100%
2	BECHI	220	VALLDUXO	220	1	440	55%	53%	100%	96%

Maximum overloads in Portugal

PiT	Bus From	V [kV]	Bus To	V [kV]	CKT	rate [MVA]	load flow w/ proj [%]	load flow w/o proj [%]	max load flow w/ proj [%]	max load flow w/o proj [%]
2	SINES	400	PEGOES	400	1	1321	101%	100%	160%	158%
2	PALMELA	400	SINES	400	2	1321	86%	86%	151%	150%
2	SINES	150	M.PEDRA	150	1	191	86%	86%	128%	127%
2	PALMELA	150	PMMP/PE	150	1	191	85%	84%	126%	125%
2	M.PEDRA	150	PMMP/PE	150	1	191	85%	84%	126%	125%
2	F.ALENT	400	SINES	400	2	1361	98%	97%	124%	123%
9	PICOTE	220	MIRANDA	220	1	229	56%	56%	113%	113%
9	PICOTE	220	MIRANDA	220	2	229	57%	57%	113%	113%
2	F.ALENT	400	ALQUEVA	400	1	1361	70%	69%	111%	110%
2	PALMELA	400	ALCOCHET	400	1	1321	72%	71%	102%	101%
2	F.ALENT	150	EVORA	150	1	218	73%	73%	100%	100%

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