MEDITERRANEAN TRANSMISSION SYSTEM OPERATORS

Deliverable 2.1.2

Detailed Project Description

02 - MAES Morocco - 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 MAES in the context of the Mediterranean Master Plan of Interconnections. Project MAES consists of a new AC interconnection between Spain and Morocco (+1000 MW AC).

The document is structured as follows. Section 2 describes the new HVAC interconnection 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 contains the active power losses calculations for the snapshots. Finally, Section 7 summarizes the investment costs required in the new HVAC link and outlines a Cost Benefit Analysis (CBA) for the project MAES.

2 Project description and data acquisition

The project MAES consists in a new interconnection between Morocco and Spain that will increase the NTC between both countries in 1000MW (additional to the 2 existing links) and to be realized through a third HVAC link.

The HVAC interconnection will have a capacity of 1000MW and a total length of around 60km, corresponding 30km to undersea cable and 30km to overhead line. This project is promoted by ONEE and REE.

Project details							
Description	***Substation (from)***	***Substation (to)***	***GTC contribution (MW)***	***Present status***	***Expected commissioning date***	***Evolution***	***Evolution driver***
New HVAC interconnection between Spain and Morocco.	TARIFA2 (ES)	BNI HARCHANE (MA)	1000	Mid-term project	TBD	Negotiations underway between ONEE and REE	Reinforce market integration with Iberian system Increase the NTC and therefore best optimizing economic opportunities of energy exchange

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

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

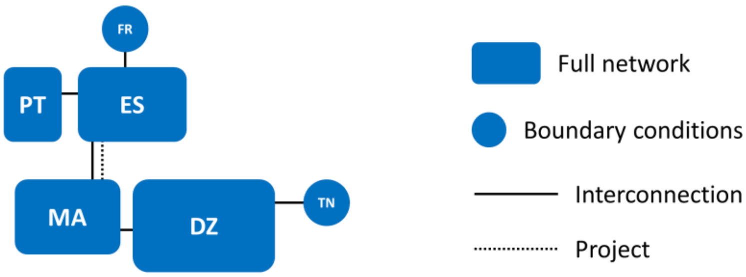

Table 1 – Electric systems involved in project MAES

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
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 DZES project
I	Algerian bus for DZIT project[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:

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

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

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 by ONEE were considered to create the snapshots corresponding to the PiTs selected. Existing interconnections with Algeria and Spain are well identified. The substation for the new HVAC connection with Spain is BNI HARCHANE (PSS/E name is D.CHAO40).

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 by REN considering the PiTs of the three projects involved in the Western Corridor. Thus, a set of eight PSS\E .sav files of the Portuguese system have been provided plus a map of the Portuguese transmission grid. These files are:

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

The interconnections with the Spanish network are 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 were afterwards 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 models 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 based on the corresponding generation limits.

3 Snapshots definition and building process

The project MAES considers a total number of 8 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. PiTs 2 and 4 were evaluated in AC. In this case, it was assumed that the total load of the PiT includes the active power losses to keep the exchanges between countries according to the PiTs obtained from the Market Studies. Accordingly, the load simulated in AC was reduced to include the losses.

The active power production comes with a breakdown of technologies. The following table shows the power balance for each of the PiTs in project MAES considering reinforcements:

	area	PG [MW]	PD [MW]	Pexport [MW]	13 MA	15 PT	17 ES	2 DZ	5 FR	19 TN
PiT1	13 MA	7705.6	9785.1	-2079.5	0.0	0.0	-1900.0	-179.5	0.0	0.0
	15 PT	5311.5	7627.6	-2316.1	0.0	0.0	-2316.1	0.0	0.0	0.0
	17 ES	44278.7	46634.1	-2355.4	1900.0	2316.1	0.0	0.0	-6571.5	0.0
	2 DZ	23774.5	23295.0	479.5	179.5	0.0	0.0	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
PiT2	area	PG [MW]	PD [MW]	Pexport [MW]	13 MA	15 PT	17 ES	2 DZ	5 FR	19 TN
	13 MA	9438.5	12432.6	-2994.0	0.0	0.0	-1994.0	-1000.0	0.0	0.0
	15 PT	3749.4	5675.9	-1926.5	0.0	0.0	-1926.5	0.0	0.0	0.0
	17 ES	31852.8	30686.7	1166.1	1994.0	1926.5	0.0	0.0	-2754.4	0.0
	2 DZ	18508.5	17208.5	1300.0	1000.0	0.0	0.0	0.0	0.0	300.0

	5 FR	0.0	-2754.4	2754.4	0.0	0.0	2754.4	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
PiT3	**area**	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	7782.6	8685.5	-903.0	0.0	0.0	-1900.0	997.1	0.0	0.0
	15 PT	5524.1	7774.3	-2250.2	0.0	0.0	-2250.2	0.0	0.0	0.0
	17 ES	67709.9	55559.7	12150.2	1900.0	2250.2	0.0	0.0	8000.0	0.0
	2 DZ	28128.8	28825.9	-697.0	-997.1	0.0	0.0	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
PiT4	**area**	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	4100.3	6402.7	-2302.5	0.0	0.0	-1900.1	-402.4	0.0	0.0
	15 PT	5475.2	5600.1	-124.9	0.0	0.0	-124.9	0.0	0.0	0.0
	17 ES	37142.5	34300.3	2842.2	1900.1	124.9	0.0	0.0	817.3	0.0
	2 DZ	15222.8	14520.4	702.4	402.4	0.0	0.0	0.0	0.0	300.0
	5 FR	0.0	817.3	-817.3	0.0	0.0	-817.3	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
PiT5	**area**	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	8304.1	9662.9	-1358.8	0.0	0.0	-1900.0	541.2	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	50846.6	52837.4	-1990.9	1900.0	2244.7	0.0	0.0	-6135.6	0.0
	2 DZ	32909.4	33150.6	-241.2	-541.2	0.0	0.0	0.0	0.0	300.0
	5 FR	0.0	-6135.6	6135.6	0.0	0.0	6135.6	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
PiT6	**area**	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	7755.0	5155.0	2600.0	0.0	0.0	1600.0	1000.0	0.0	0.0
	15 PT	4396.6	7712.3	-3315.8	0.0	0.0	-3315.8	0.0	0.0	0.0
	17 ES	41662.7	45139.0	-3476.3	-1600.0	3315.8	0.0	0.0	-5192.1	0.0
	2 DZ	20144.1	20844.1	-700.0	-1000.0	0.0	0.0	0.0	0.0	300.0
	5 FR	0.0	-5192.1	5192.1	0.0	0.0	5192.1	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	7129.6	9288.85	353.86	-2159.24	0	0	-1900	-259.24	0
	15 PT	6124.06	7204.95	113.71	-1080.89	0	0	-1080.89	0	0

	17 ES	50004.74	43851.77	1237.13	6152.97	1900	1080.89	0	0	3172.07
	2 DZ	26542.12	25982.88	500.85	559.24	259.24	0	0	0	0
	5 FR	0	3172.07	0	-3172.07	0	0	-3172.07	0	0
	19 TN	0	300	0	-300	0	0	0	-300	0
PiT8	**area**	**PG [MW]**	**PD [MW]**	**Pexport [MW]**	**13 MA**	**15 PT**	**17 ES**	**2 DZ**	**5 FR**	**19 TN**
	13 MA	7900.99	6586.01	269.34	1314.98	0	0	1599.98	-285	0
	15 PT	6557.04	7775.61	73.64	-1218.58	0	0	-1218.58	0	0
	17 ES	54791.45	49231.36	1375.36	5560.09	-1599.98	1218.58	0	0	5941.5
	2 DZ	26667.31	26082.31	517.59	585	285	0	0	0	0
	5 FR	0	5941.5	0	-5941.5	0	0	-5941.5	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 MAES

4 Power flow and security analysis

This section presents the criteria agreed to run the power flow and N-x security analysis for the different snapshots built for the PiTs of the project MAES. 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 following table summarizes the voltage buses limits in N (Table 5) and in N-1 (Table 6) situations for Algeria, Morocco, Portugal and Spain used in the AC analysis.

Country	**400 kV**		**225 kV/220 kV**		**150 kV**	
DZ	380	420	205	235	141	159
MA	380	420	209	245	135	165
PT	380	420	209	245	142	165
ES	390	420	205	245		

Table 5 – Voltages limits under normal operation conditions

Country	**400 kV**		**225 kV/ 220 kV**		**150 kV**	
DZ	380	420	198	242	135	165
MA	380	420	205	245	135	165
PT	372	420	205	245	140	165

Country	400 kV		225 kV/ 220 kV		150 kV	
ES	380	435	205	245		

Table 6 – Voltages limits under N-1 operation conditions

The reference bus for the merged network is VILLARIN 400kV 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

No significant overloads associated to the new interconnection were identified in the Algerian system, thus no reinforcements were defined for the network of this country.

It is worth mentioning that the N-1 contingency of a new 1000MW nuclear power plant in Algeria 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

The Moroccan system is significantly affected by the project MAES. The security analysis resulted in the following reinforcements:

- Two new 400kV OHL of 220km between substations BNI HARCHANE and SEHOUL
- A new 400kV OHL of 20km between substations BNI HARCHANE and MELOUSSA
- A new 225kV OHL of 19km between substations MELOUSSA and TANGER
- A new 600MVA transformer in substations SEHOUL and the upgrade of the two existing ones from 450MVA to 600MVA

These reinforcements are highlighted in the following map:

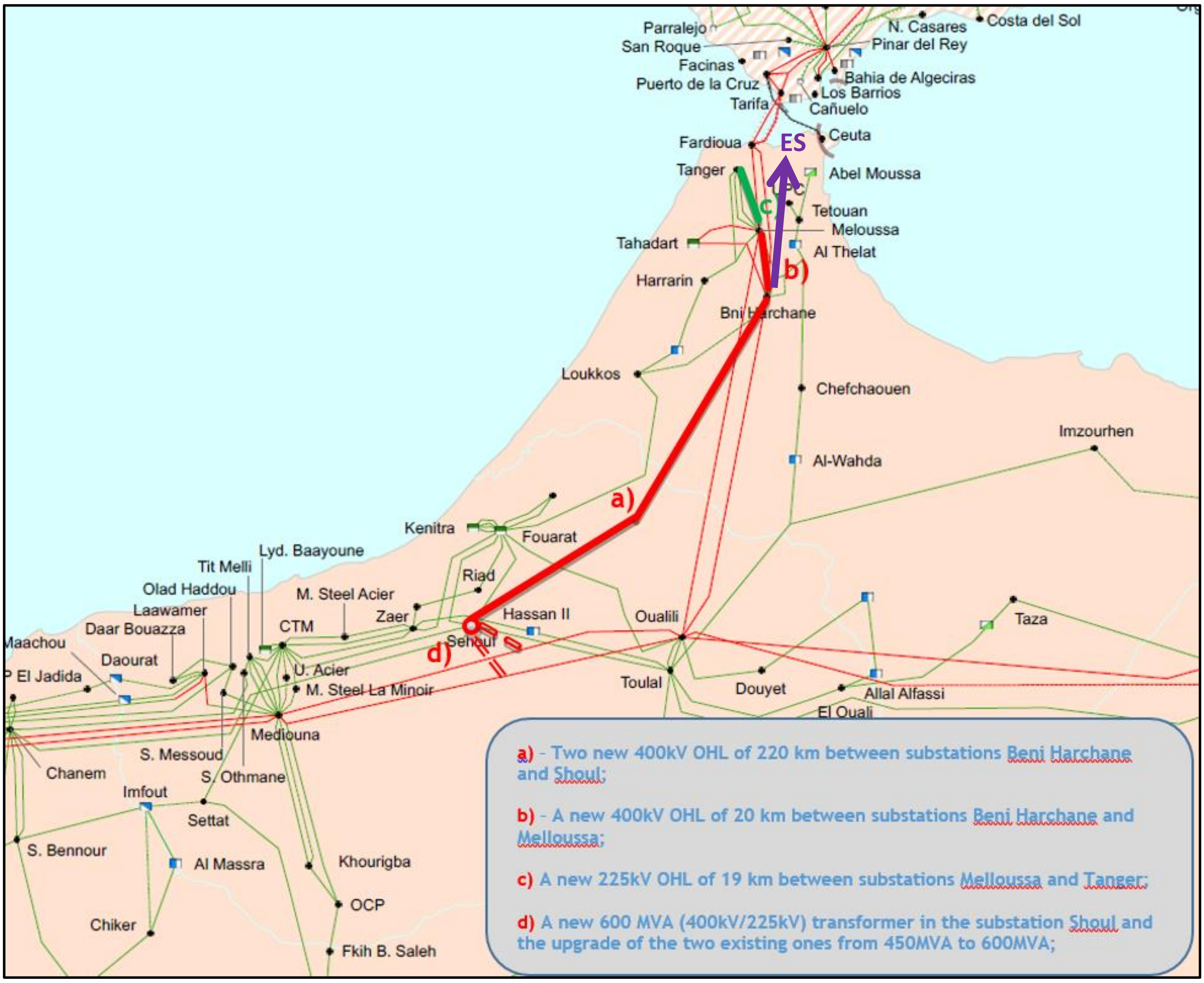

Figure 1 – Internal reinforcements in Morocco which were considered in order to accommodate the 1000MW flow between Spain and Morocco (Med-TSO network studies)

The estimate for the total investment cost in Morocco grid is **70M€.**

It is worth mentioning that the existing interconnection between Spain and Morocco can sustain contingencies of the new HVAC project up to 500MW without requiring reinforcement.

Spain

The Spanish system is affected by the project MAES in the 220kV and in the 400kV network. The new AC interconnection will depart from the new 400kV substation TARIFA2 which is connected to substation PTO. CRUZ via a double OHL of 10km. The following reinforcements were also identified:

- Two new substations 400kV: GUADAIRA and AZNALCOYAR
- Two new 600 MVA transformers 400kV/220kV in CARTUJA
- New double OHL 400kV of 10km between TARIFA and PTO. CRUZ
- New double OHL 400kV of 90km between CARTUJA and PTO. CRUZ
- New double OHL 400kV of 20km between D. RODRIGO and GUADAIRA
- New double OHL 220kV of 33km between FACINAS and PARRALEJO
- New single OHL 220kV of 16km between FACINAS and PTO. CRUZ
- New single OHL 400kV of 45km between GUADAIRA and AZNALCOYAR
- New single OHL 400kV of 20km between AZNALCOYAR and GUILLENA

The investments estimate is 10M€ for the two transformers, 12M€ for the new substations, and 122M€ for the network upgrading, totaling 144M€.

The calculations 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 MAES 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 MAES and without the project MAES. Redispatch of generation according to Market Studies was taken into account to obtain equivalent PiTs without the project MAES.

The simulations showed that without the project MAES 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 MAES, 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 MMP 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 MAES of more than the 15%, Table 7 shows the lines that need concrete reinforcements. Reconductoring interventions are also considered sufficient for the lines with an overload less than 30% of the rate.

PiT	Bus From	V [kV]	Bus To	V [kV]	ID	Length [km]	Rate [MVA]	Max Loading w/ MAES [MVA]	Max Loading w/o MAES [MVA]	Difference [%]
3	PSEVILLA	220	CENT_NPB	220	1	7.5	441	645.61	515.44	29.52
3	VIRGENRO	220	CENT_NPB	220	1	4.9	441	595.97	480.27	26.24
3	QUINTOS	220	VIRGENRO	220	1	3.6	441	536.42	420.73	26.23
8	L.MONTES	220	LOSRAMOS	220	1	12.41	210	230.42	177.7	25.1
7	CARTUJA	220	DRODRI_B	220	1	88.9	350	388.16	301.59	24.73
2	ALARCOS	220	MANZARES	220	1	58.42	180	242.58	210.38	17.89
7	DOSHMNAS	220	MIRABAL	220	1	70	350	386.96	329.76	16.34
8	TRUJILLO	220	MERIDA	220	1	76.17	180	488.54	459.37	16.21

Table 7 – Circuits identified in Spain for reinforcement in order to accommodate the 1000MW flow between Spain and Morocco (Med-TSO network studies)

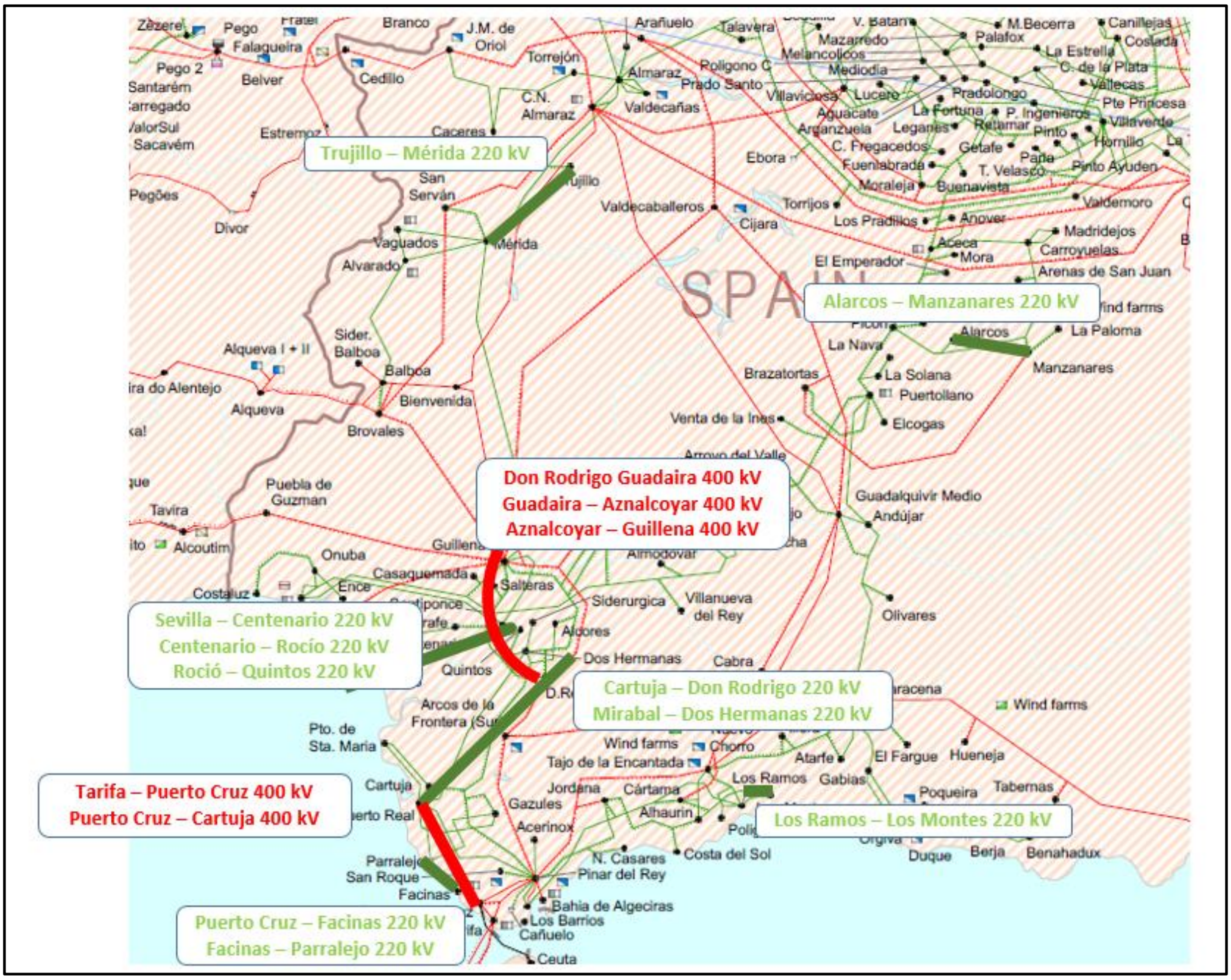

Figure 2 – Internal reinforcements in Spain which were considered in order to accommodate the 1000MW flow between Spain and Morocco (Med-TSO network studies)

The estimate of the investment cost in the lines identified in Table 7 is around 33M€. Therefore, the total investment cost for the concrete reinforcements in Spain calculated with the above analysis is 33M€ + 144M€ = **177M€.**

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 led to the identification of reinforcements needs equivalent to 67.394 MVA*km in 220kV lines and 115.498 MVA*km in 400kV lines. The estimated cost of this reinforcements needs if solved by uprating the overloaded lines is around 17M€.

Therefore, the estimate of the total investment cost in Spain due to the project MAES by REE is 33M€ + 144M€ + 17M€ = **194M€**.

For the purpose of the MMP it can be concluded that independent methodologies detected costs for internal reinforcements in Spain in the range of **177M€ - 194M€.**

Portugal

No internal reinforcements due to the project MAES are envisaged in the Portuguese network.

6 Estimation of active power losses

Internal losses in each country

To evaluate the performance of the new HVAC interconnection project plus the planned reinforcements, the active power losses have been computed for: a) the snapshots with the reinforcements identified; and b) the snapshots without the interconnection project MAES 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	381.6	377.0	-4.6
2	247.0	243.3	-3.7
3	569.0	636.3	67.3
4	248.0	204.6	-43.4
5	620.2	674.7	54.5
6	390.7	382.1	-8.6
7	477.8	481.3	3.5
8	464.3	495.6	31.3

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

Morocco	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	456.4	355.8	-100.6
2	640.6	591.2	-49.4
3	242.3	194.1	-48.2
4	387.4	271.2	-116.2
5	352.4	276.7	-75.7
6	212.6	315.5	102.9
7	463.5	364.1	-99.4
8	194.2	269.4	75.2

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

Portugal	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	79.8	82.0	2.2
2	64.2	68.0	3.8
3	282.5	290.3	7.8
4	62.6	70.0	7.4
5	85.6	84.3	-1.3
6	89.1	87.2	-1.9
7	127.1	120.9	-6.2
8	80.6	84.2	3.6

Table 10 – Comparison of the active power losses for each snapshot, with and without the interconnection project MAES and associated reinforcements, for the Portuguese system

Spain	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	650.5	693.3	42.8
2	428.9	505.7	76.8
3	3360.3	3293.7	-66.6
4	534.5	598.2	63.7
5	763.7	774.7	11.0
6	585.7	607.5	21.8
7	1262.1	1227.1	-35.0
8	1300.8	1404.1	103.3

Table 11 – Comparison of the active power losses for each snapshot, with and without the interconnection project MAES and associated reinforcements, for the Spanish system

Losses in the new HVAC interconnection

Since the power system is weakly meshed between Spain and Morocco, it can be assumed that physical flows on the physical interconnections are similar to commercial exchanges. The calculation of the losses in the new HVAC interconnection was made for the four scenarios considering the 400kV voltage level. The following table shows the annual losses estimate for the HVAC link and scenario:

Scenario	Annual Losses (GWh)
S1	25.36
S2	21.52
S3	20.61
S4	13.78

Table 12 – Annual losses estimate for the new HVAC link of the project MAES

7 Estimation of investment cost

The new HVAC link between Spain and Morocco is composed of a configuration of two three-phase AC cables. The total length of the new link is 60km of which 30km is cable (undersea) and 30km is OHL. The estimate of the undersea AC cable cost is 3.8M€/km including installation while the estimate for the OHL is 0.5M€/km. Thus, the estimate for the total conductor cost is 129M€. In each end substations (TARIFA2 and BNI HARCHANE) it is necessary to install two AIS bays, totaling 3M€. Shunt reactors of 360Mvar are also foreseen to be installed in each substation to compensate the reactive power produced by the capacitance of the cables. The cost of the shunt reactors is 13M€. In the Spanish side, the new AC interconnection will depart from a new 400kV substation, named TARIFA2, which is connected to substation PTO. CRUZ via a double OHL of 10km with an estimated investment cost of 5M€. Finally, the estimate for the total investment cost in the new HVAC interconnection between Spain and Morocco is **150M€.**

A Cost Benefit Analysis 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 P2 - MAES														
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)		MA	1900	2900	1000	1900	2900	1000	1900	2900	1000	1900	2900	1000
		ES	12100	13100	1000	12100	13100	1000	12100	13100	1000	12100	13100	1000
Interconnection Rate (%)*		MA	9.0%	13.7%	4.7%	9.0%	13.7%	4.7%	7.8%	11.9%	4.1%	8.2%	12.5%	4.3%
		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)	80			140			63			130		
	B2-RES	(GWh/y)	70			410			130			460		
	B3-CO_2	(kT/y)	950			-950			550			-900		
	B4 - Losses	(M€/y)	8.6			8.2			8.0			8.5		
		(GWh/y)	168			165			156			157		
	B5a-SoS Adequacy	(MWh/y)	120			180			100			60		
	B5b-SoS System Stability													
Residual Impact Indicators	S1- Environmental Impact													
	S2-Social Impact													
	S3-Other Impact													
Costs	C1-Estimated Costs**	(M€)	397-414											

Table 13 – Cost Benefit Analysis for the MAES project

8 References

1	Snapshots building process	Share point
2	Guide for setting up grid models for Network studies	Share point
3	Network Analysis and Reinforcement Assessment	Share point

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 [%]
3	SALTERAS	220	GUILLENA	220	1	310	119%	129%	338%	334%
3	SANTIPOB	220	CENT_NPB	220	1	350	235%	211%	323%	310%
8	LA PLANA	400	GAUSSA	400	1	880	144%	138%	246%	237%
8	ELIANA	400	GODELLET	400	1	1500	164%	159%	226%	220%
8	ELEMPERA	220	MORA	220	1	170	173%	169%	223%	216%
3	CARMONA	220	VNUEVREY	220	1	340	80%	74%	217%	214%
8	ACECA	220	MORA	220	1	170	163%	158%	212%	206%
3	ALMODOVA	220	CASINPB	220	1	350	134%	136%	211%	208%
3	ALMARAZ	400	GUADAME	400	1	690	135%	145%	199%	212%
8	CATADAU	400	TORRENTE	400	1	1500	90%	88%	191%	186%
8	ELIANA	400	GAUSSA	400	1	1370	121%	117%	191%	184%
8	ESCATROB	220	ESPARTAL	220	1	240	133%	132%	190%	188%
3	LA SERNA	220	TUDELA	220	2	320	56%	55%	184%	184%
3	MERIDA	220	VAGUADAS	220	1	250	104%	104%	182%	180%
8	ALMARAZ	220	TRUJILLO	220	1	180	113%	107%	180%	171%
3	CASACAMP	220	MAZARRED	220	1	462	101%	104%	177%	181%
8	ROJALES	220	SMSALINN	220	1	600	118%	114%	176%	170%
3	ALVARADO	220	VAGUADAS	220	1	260	75%	73%	175%	173%
3	GARO-BAR	400	GUENES	400	1	940	126%	127%	175%	176%
3	ALMODOVA	220	VNUEVREY	220	1	340	94%	98%	174%	171%
8	ESCATROB	220	AUBALS	220	1	310	131%	130%	174%	173%
3	MBECERRA	220	PROSPERI	220	1	240	64%	66%	172%	176%
8	ALBAL	220	CATADAU	220	1	330	101%	98%	171%	167%
8	ELIANA	220	PUZOL	220	1	430	76%	73%	171%	165%
3	ALMARAZ	400	CARMONIT	400	1	1470	125%	127%	170%	174%
6	JALON	220	MAGALLON	220	1	370	90%	87%	170%	165%
6	JALON	220	MAGALLON	220	2	370	90%	87%	170%	165%
8	ELIANA	400	LA PLANA	400	1	1370	97%	93%	170%	164%
8	CALDERS	400	ISONA	400	1	730	124%	124%	169%	169%
8	ELCHE2	220	SALADAS	220	1	530	102%	98%	169%	161%
8	MORALEJA	400	VILLAVIC	400	1	780	128%	120%	168%	158%
3	ALDEADAV	400	ARANUELO	400	1	1280	124%	127%	167%	172%
3	ROMICA	400	OLMEDILL	400	1	1320	108%	110%	167%	170%
3	ROMICA	400	OLMEDILL	400	2	1320	108%	110%	167%	170%

3	AYORA	400	COFRENTE	400	2	1100	58%	59%	167%	169%
8	ELIANA	400	TORRENTE	400	1	1500	63%	61%	167%	162%
8	MORVEDRE	220	SAGUNTO	220	1	430	96%	92%	165%	159%
3	BENEJAMA	400	SAX	400	1	1480	116%	119%	165%	168%
3	ALDEADAV	220	VILLARIN	220	3	250	63%	65%	165%	170%
3	ALDEADAV	220	VILLARIN	220	4	250	63%	65%	165%	170%
4	CASTRELO	220	AMOEIRO	220	1	230	77%	72%	164%	157%
3	BENEJAMA	400	MONTESA	400	1	1340	124%	126%	163%	166%
3	CATADAU	400	MONTESA	400	1	1340	123%	125%	162%	165%
3	LA SERNA	220	TUDELA	220	1	290	49%	48%	161%	161%
8	TARRAGON	220	REUS II	220	1	310	118%	118%	161%	161%
3	CANTALAR	220	ALICANTE	220	1	450	113%	115%	160%	163%
3	CAMPONAC	220	EL COTO	220	1	433	66%	67%	160%	162%
3	ALMARAZ	400	ALANGE	400	1	1430	93%	96%	160%	165%
3	CANILLEJ	220	SIMANCAS	220	1	529	82%	83%	159%	161%
3	GRIJOTA	400	BUNIEL	400	1	950	115%	118%	159%	162%
3	ALANGE	400	BIENVENI	400	1	1430	92%	95%	159%	164%
8	MORVEDRE	220	PUZOL	220	1	430	64%	61%	158%	152%
8	ELEMPERA	220	PICON	220	1	180	110%	104%	157%	149%
3	CATADAU	220	JIJONA	220	1	260	109%	111%	157%	160%
8	ALBAL	220	TORRENTE	220	1	330	86%	83%	156%	152%
8	GODELLET	400	REQUENA	400	1	910	122%	120%	156%	153%
3	MTEBELLO	220	VILLAJOY	220	1	360	86%	87%	155%	158%
8	MINGLANI	400	OLMEDILL	400	1	990	102%	100%	154%	150%
8	PALMERAL	220	TORLLANO	220	1	506	124%	121%	154%	149%
3	BENEJAMA	220	CASTALLA	220	1	410	85%	86%	154%	156%
3	MEDINACE	400	RUEDA	400	1	1340	112%	114%	153%	157%
8	ASCO	400	ESCATRON	400	1	840	110%	110%	153%	153%
8	ELCHE2	220	ROJALES	220	1	590	93%	90%	153%	147%
3	MAGALLON	400	TERRER	400	1	1335	111%	114%	153%	156%
3	MAGALLON	400	RUEDA	400	1	1335	111%	113%	152%	155%
3	CATADAU	400	GODELLET	400	1	1600	75%	77%	152%	154%
8	ARAGON	400	MUDEJAR	400	1	840	83%	81%	152%	148%
8	ARAGON	400	MUDEJAR	400	2	840	83%	81%	152%	148%
3	ROCAMORA	400	TREMENDO	400	1	1290	56%	57%	151%	155%
3	CAMPANAR	400	PINILLA	400	1	1960	93%	96%	151%	155%
3	MEDINACE	400	TRILLO	400	1	1310	108%	111%	150%	154%
8	CAMPOAMO	220	DESF.SMS	220	1	600	110%	106%	150%	142%
3	CEDILLO	400	JM.ORIOL	400	1	1280	105%	107%	150%	153%
4	TUDELA	220	MAGALLO2	220	1	330	56%	55%	149%	146%
3	GRIJOTA	400	BRIVIESC	400	1	950	116%	119%	149%	152%
3	ACECA	220	VALDMORO	220	1	560	108%	110%	148%	152%
3	STA ANNA	400	SAX	400	1	1440	98%	101%	148%	151%
8	ALVARADO	220	MERIDA	220	1	260	88%	87%	147%	146%
3	ABRERA	220	PUJALT	220	1	260	95%	94%	147%	146%

8	COSLADA	220	VILLAVER	220	1	315	83%	79%	147%	142%
3	ESCUCHA	220	VALDECON	220	1	300	83%	84%	147%	148%
3	PSEVILLA	220	CENT_NPB	220	1	441	93%	72%	146%	117%
3	GARO-BAR	400	ICHASO	400	1	1030	100%	101%	146%	147%
3	GURREA	220	SABINANI	220	2	220	90%	90%	146%	145%
3	GURREA	220	ESQUEDAS	220	1	220	92%	91%	146%	145%
3	PALENCIA	220	RENEDO	220	1	304	78%	80%	145%	149%
3	C.COLON	220	TORARENI	220	2	170	75%	79%	145%	153%
3	ARGANDA	220	LOECHESB	220	1	440	93%	95%	144%	149%
3	CARDIEL	220	MEQUINEN	220	1	210	81%	80%	143%	141%
3	LA POBLA	220	RUBIO	220	1	280	78%	78%	143%	143%
4	CHANTADA	220	AMOEIRO	220	1	230	55%	51%	143%	136%
8	ISONA	400	SENTMENA	400	1	730	85%	85%	142%	142%
8	COFRENTE	400	LA MUELA	400	2	1170	79%	78%	142%	140%
3	MAJADAHO	220	VALLARCI	220	1	360	94%	96%	142%	145%
3	GRIJOTA	400	HERRERA	400	1	1040	92%	94%	142%	145%
8	COFRENTE	400	LA MUELA	400	1	1170	78%	77%	142%	139%
8	LASELVA	220	AUBALS	220	1	410	109%	108%	141%	141%
4	TRUJILLO	220	MERIDA	220	1	180	72%	57%	141%	116%
3	TERRER	400	TRILLO	400	1	1470	102%	104%	140%	143%
4	LA POBLA	220	TSESUE	220	1	320	103%	102%	140%	138%
8	ALDAIA	220	TORRENTE	220	1	430	79%	76%	139%	135%
3	SABINANI	220	ESQUEDAS	220	1	220	84%	83%	138%	137%
8	GRADO	220	MONZON	220	1	210	48%	47%	138%	137%
8	VANDELLO	400	CAPELLAD	400	1	930	106%	105%	138%	137%
8	ARAGON	400	VANDELLO	400	1	840	81%	80%	138%	137%
2	CARRIO	220	REBORIA	220	1	530	102%	101%	138%	136%
3	HUELVES	220	MORATA	220	1	360	83%	81%	137%	136%
3	COMPOSTI	400	MONTEARE	400	1	900	79%	81%	137%	140%
8	EALMARAZ	220	CALERA	220	1	320	101%	98%	137%	131%
8	GODELLET	220	TORRENTE	220	1	520	70%	69%	136%	133%
8	MEDIANO	220	P.SUERT	220	1	210	46%	46%	136%	135%
6	MANFIGUE	220	PALAU	220	1	260	53%	53%	135%	135%
3	VIRGENRO	220	CENT_NPB	220	1	441	61%	51%	135%	109%
3	CRODRIGO	400	HINOJOSA	400	1	1280	107%	110%	135%	138%
8	LUCERO	220	VILLAVIC	220	1	360	82%	81%	135%	130%
2	ALARCOS	220	MANZARES	220	1	180	73%	68%	135%	117%
8	TALAVERA	220	CALERA	220	1	320	99%	96%	135%	130%
8	MINGLANI	400	REQUENA	400	1	1020	104%	102%	134%	131%
8	ACECA	220	CARROYUE	220	1	630	94%	93%	134%	131%
3	SAGUNTO	220	VALLDUXO	220	1	440	76%	77%	134%	137%
3	A.LEYVA	220	PQINGENI	220	1	510	81%	82%	134%	135%
8	GUENES	220	TGUENES	220	1	360	94%	94%	134%	134%
3	ALDEADAV	220	VILLARIN	220	1	330	51%	53%	134%	138%
3	ALDEADAV	220	VILLARIN	220	2	330	51%	53%	134%	138%

3	S.CUGAT	220	C.JARDIB	220	1	240	97%	97%	133%	133%
3	ALMARAZ	400	ARSERVAN	400	2	1760	88%	91%	133%	136%
3	BEGUES	400	ESPLUGA	400	1	940	88%	88%	133%	133%
3	CARMONIT	400	ARSERVAN	400	1	1470	88%	91%	133%	137%
3	NOVELDA	220	PETREL	220	1	410	67%	69%	132%	135%
6	PENAFLOR	220	VILLANUE	220	1	280	39%	35%	132%	128%
3	HUELVES	220	VILLARES	220	1	360	77%	76%	132%	131%
3	ESCATRON	400	FUENDETO	400	1	1480	83%	84%	132%	133%
3	MUDARRA	400	TORDESIL	400	1	1360	105%	108%	132%	135%
3	BASAURI	220	TGUENES	220	1	360	82%	82%	131%	131%
8	ACECA	220	PICON	220	1	320	100%	96%	131%	127%
8	RUBI	400	MAIALS	400	1	820	98%	98%	131%	130%
3	ALMARAZ	400	VILLAVIC	400	1	1280	103%	106%	130%	134%
3	ALMARAZ	400	VILLAVIC	400	2	1280	103%	106%	130%	134%
8	LASELVA	220	REUS II	220	1	310	67%	67%	130%	130%
3	CAMPOAMO	220	S.P.PINA	220	1	500	92%	94%	130%	133%
3	POLGORDO	400	LA ROBLA	400	1	820	84%	85%	129%	131%
3	ARSNJUA	220	MANZARES	220	1	630	66%	68%	129%	134%
3	AMOREBIE	400	ICHASO	400	1	940	62%	61%	129%	129%
3	CANILLEJ	220	COSLADA	220	1	410	68%	68%	129%	130%
3	CANILLEJ	220	COSLADA	220	2	410	68%	68%	129%	130%
3	AGUACATE	220	POLIGONC	220	1	470	73%	73%	129%	130%
3	HORTALEZ	220	PROSPERI	220	1	240	21%	23%	129%	133%
3	RAMBLETA	220	VALLDUXO	220	1	500	69%	70%	128%	131%
6	CENTELLE	220	SENTMENA	220	1	220	21%	20%	128%	127%
3	CRODRIGO	400	ALMARAZ	400	1	1280	100%	103%	128%	132%
5	GUILLE_B	220	CENT_NPB	220	1	170	73%	68%	127%	126%
8	LA PLANA	400	CAMARLES	400	1	1380	75%	73%	128%	123%
8	LEGANES	220	LUCERO	220	1	280	59%	57%	127%	121%
8	RUBI	400	DESVERN	400	1	1010	94%	94%	127%	126%
8	CARDIEL	220	ARNERO	220	1	210	35%	36%	126%	126%
3	PALMAR	400	ROCAMORA	400	1	1280	81%	85%	126%	131%
3	PALMAR	400	ROCAMORA	400	2	1280	81%	85%	126%	131%
8	BSONUEVO	220	GRAMANTA	220	1	414	82%	82%	126%	126%
8	JUNEDA	220	PERAFORT	220	1	280	75%	74%	125%	125%
8	MORATA	400	TVELASCO	400	1	780	60%	60%	125%	123%
3	ALDEADAV	400	HINOJOSA	400	1	1380	99%	102%	125%	128%
6	CONSTANT	220	TARRAGON	220	1	320	8%	8%	125%	125%
8	COFRENTE	400	GODELLET	400	1	1500	68%	66%	125%	123%
3	BESCANO	400	SENTMENA	400	1	2030	72%	72%	125%	125%
3	RIUDAREN	400	VIC	400	1	2030	53%	53%	125%	125%
3	POLGORDO	400	SAMA	400	1	820	79%	80%	125%	127%
3	RUBI	400	VANDELLO	400	1	930	95%	96%	124%	125%
8	GARO-BAR	400	LORA	400	1	990	96%	94%	124%	121%
8	MORATA	220	VILLAV B	220	1	350	83%	83%	123%	123%

8	ALMARAZ	400	VILLAMIE	400	1	720	80%	76%	123%	117%
3	PIEROLA	220	RUBIO	220	1	350	72%	71%	123%	123%
8	ARANUELO	400	MORATA	400	1	720	95%	91%	123%	117%
3	EJEACAB	400	JACA	400	1	1800	61%	61%	123%	123%
3	EJEACAB	400	JACA	400	2	1800	61%	61%	123%	123%
8	ARANUELO	400	MORATA	400	2	720	95%	91%	123%	117%
8	ASCO	400	SENTMENA	400	1	940	79%	79%	123%	123%
8	ASCO	400	SENTMENA	400	2	940	79%	79%	123%	123%
3	GUILLENA	220	SANTIPOB	220	2	350	41%	30%	123%	108%
3	MUDEJAR	400	MORELLA	400	1	1800	74%	75%	123%	124%
3	MUDEJAR	400	MORELLA	400	2	1800	74%	75%	123%	124%
3	AGUAYO	400	VELILLA	400	1	930	95%	96%	122%	124%
8	ASCO	400	PIEROLA	400	1	940	77%	77%	122%	122%
8	AYORA	400	COFRENTE	400	1	1100	88%	85%	122%	118%
3	PALMERAL	220	S.VICENT	220	1	506	58%	59%	122%	124%
3	LASELVA	220	REUS II	220	2	441	63%	63%	122%	122%
3	QUINTOS	220	VIRGENRO	220	1	441	47%	37%	122%	95%
8	LA SERNA	400	EJEACAB	400	1	1335	44%	45%	122%	120%
4	BELESAR	220	CHANTADA	220	1	311	65%	63%	122%	116%
8	BENEJAMA	220	JIJONA	220	2	360	58%	58%	121%	120%
3	RAMBLETA	220	ASSEGADO	220	1	510	63%	64%	121%	124%
3	OLMEDILL	220	VILLARES	220	1	360	66%	66%	121%	121%
8	BENEJAMA	220	JIJONA	220	1	360	58%	58%	121%	119%
8	ET.CERR1	220	CERPLATA	220	1	420	66%	65%	121%	119%
8	ET.CERR1	220	VILLAVER	220	1	420	66%	65%	121%	119%
8	BEGUES	400	VILADECA	400	1	1010	76%	76%	121%	120%
6	ESCATROB	220	MEQUINEN	220	1	230	70%	70%	121%	120%
8	CATADAU	400	LA MUELA	400	2	1170	79%	78%	120%	118%
3	SAGUNTO	220	VALLDUXO	220	2	500	69%	70%	120%	123%
6	PENAFLOR	400	EJEACAB	400	1	1340	93%	91%	120%	118%
8	CATADAU	400	LA MUELA	400	1	1170	79%	78%	120%	118%
3	BALSICAS	220	PALMAR	220	1	490	65%	65%	120%	123%
8	DESF.SMS	220	SMSALINS	220	1	750	88%	85%	120%	114%
3	MIRASIER	220	VALLARCI	220	1	360	72%	74%	120%	123%
3	HOSPTLET	220	VILADECA	220	1	260	66%	66%	120%	120%
3	HOSPTLET	220	VILADECA	220	2	260	66%	66%	120%	120%
8	GRADO	220	MEDIANO	220	1	240	41%	41%	120%	119%
1	GURREA	220	VILLANUE	220	1	207	67%	65%	120%	116%
3	VILLALBI	220	VILLATOR	220	1	304	93%	94%	119%	120%
3	GUILLENA	220	SANTIPON	220	4	350	52%	47%	119%	110%
8	LOECHES	400	MORATA	400	1	1460	97%	92%	119%	114%
3	ABRERA	220	RUBI	220	1	260	67%	66%	119%	118%
3	BESCANO	400	RIUDAREN	400	1	2030	47%	47%	118%	118%
3	PETREL	220	ELDA	220	1	410	53%	54%	118%	120%
1	GURREA	220	VILLANUE	220	2	210	66%	64%	118%	114%

3	JM.ORIOL	400	CANAVERA	400	1	1420	70%	71%	118%	120%
3	ARAGON	400	N.MEQUIN	400	1	1310	69%	70%	118%	119%
3	ABADIANO	220	VITORIA	220	1	327	64%	64%	118%	118%
6	A.ZINC	220	TABIELLA	220	1	270	59%	59%	118%	117%
6	A.ZINC	220	TABIELLA	220	2	270	59%	59%	118%	117%
6	ASCO	400	ESPLUGA	400	1	940	88%	88%	118%	117%
3	PIEROLA	400	CAPELLAD	400	1	930	50%	50%	117%	118%
7	TVELASCA	220	PINTOAYU	220	1	560	66%	68%	117%	120%
8	ACECA	220	ANOVER	220	1	560	75%	74%	117%	115%
3	CASAQUEM	220	ONUBA	220	1	350	46%	48%	117%	116%
3	CASAQUEM	220	GUILLENA	220	1	350	71%	68%	117%	116%
3	JUNDIZ	220	PUENTELA	220	1	539	84%	84%	117%	117%
2	CARRIO	220	TABIELLA	220	2	530	38%	38%	117%	116%
8	ELHORNIL	220	VILLAVER	220	1	415	60%	58%	116%	114%
7	ANOVER	220	TVELASCA	220	1	630	72%	73%	116%	118%
3	FAUSITA	220	HOYAMORE	220	1	530	81%	83%	116%	120%
8	VIENTOS	220	MARIA	220	1	370	64%	62%	116%	112%
8	VIENTOS	220	MARIA	220	2	370	64%	62%	116%	112%
3	TABIELLA	220	GOZON	220	2	530	65%	65%	116%	117%
4	ESCALONA	220	TESCALON	220	1	320	79%	80%	116%	115%
4	ESCALONA	220	TSESUE	220	1	320	79%	80%	116%	115%
8	CERPLATA	220	PRINCESA	220	1	440	80%	78%	116%	112%
3	LA PLANA	400	MORELLA	400	2	1800	68%	70%	116%	119%
3	LA PLANA	400	MORELLA	400	3	1800	68%	70%	116%	119%
7	ET.LOEC1	400	LOECHES	400	1	1380	90%	91%	116%	118%
7	ET.LOEC1	400	ET.SSRR1	400	1	1380	90%	91%	116%	118%
7	SS REYES	400	ET.SSRR1	400	1	1380	90%	91%	116%	118%
3	CANTALAR	220	JIJONA	220	1	360	19%	20%	116%	117%
3	A.LEYVA	220	ARGANZUE	220	1	520	63%	64%	115%	116%
8	MORATA	220	TORRECIL	220	1	490	57%	56%	115%	114%
3	BECHI	220	VALLDUXO	220	1	440	63%	64%	115%	117%
3	ROMICA	400	MANZARES	400	1	1820	75%	77%	115%	119%
3	ROMICA	400	MANZARES	400	2	1820	75%	77%	115%	119%
5	SALTERAS	220	SANTIPOB	220	1	350	98%	94%	115%	111%
6	PC_FAVE2	220	S.CUGAT	220	1	240	41%	41%	115%	115%
8	MEDIODIA	220	PRINCESA	220	1	370	72%	70%	114%	110%
7	ELHORNIL	220	PINTOAYU	220	1	560	63%	65%	114%	117%
3	GRIJOTA	400	MUDARRA	400	1	910	74%	76%	114%	117%
3	ESCATROA	220	ESCATROB	220	1	600	50%	50%	114%	114%
8	ET.CERR2	220	CERPLATA	220	1	450	64%	63%	114%	112%
8	ET.CERR2	220	VILLAVER	220	1	450	64%	63%	114%	112%
7	ALARCOS	220	PICON	220	1	320	30%	34%	114%	120%
3	CASINPB	220	AZAHARA	220	1	388	47%	51%	114%	116%
8	MAGALLON	400	EJEACAB	400	1	1335	63%	62%	113%	111%
3	HOYAMORE	220	S.P.PINA	220	1	500	76%	78%	113%	117%

8	MAGALLON	400	EJEACAB	400	2	1340	64%	63%	113%	111%
7	EL COTO	220	SIMANCAS	220	1	404	53%	54%	113%	116%
3	PICON	220	P.LLANO	220	1	320	50%	58%	113%	120%
3	LASOLANA	220	P.LLANO	220	1	320	16%	24%	113%	107%
3	CAMPOAMO	220	FAUSITA	220	1	490	65%	67%	113%	115%
8	ESCUCHA	220	HIJAR	220	1	210	59%	58%	113%	112%
3	BEGUES	400	GARRAF	400	1	1010	81%	82%	112%	113%
3	FUENCARR	400	SS REYES	400	1	910	67%	68%	112%	114%
8	ACECA	220	PRADILLO	220	1	545	61%	60%	112%	110%
3	LASOLANA	220	PICON	220	1	320	54%	61%	112%	118%
3	ANOIA	220	ISONA	220	1	260	58%	58%	112%	112%
3	ALCORES	220	CARMONA	220	1	310	55%	46%	112%	102%
3	NOVELDA	220	SALADAS	220	1	450	51%	52%	112%	114%
3	NOVELDA	220	SALADAS	220	2	450	51%	52%	112%	114%
8	GARO-BAR	400	BUNIEL	400	1	950	79%	76%	111%	108%
3	LA ESTRE	220	MORATA	220	1	470	78%	78%	111%	113%
8	SENGRACI	400	LA SERNA	400	1	840	73%	73%	111%	110%
6	TORRECIL	220	VILLAV B	220	1	420	58%	57%	111%	110%
3	MEQUINEN	400	N.MEQUIN	400	1	1310	63%	64%	111%	113%
7	CARTUJA	220	DRODRI_B	220	1	350	41%	38%	111%	86%
3	CASACAMP	220	NORTE	220	2	499	70%	72%	111%	113%
8	CASACAMP	220	MBECERRA	220	1	240	47%	45%	111%	107%
3	OLMEDILL	400	TRILLO	400	1	1800	76%	76%	111%	111%
3	ICHASO	400	VITORIA	400	1	1030	85%	86%	111%	112%
7	DOSHMNAS	220	MIRABAL	220	1	350	50%	47%	111%	94%
8	VILADECA	400	DESVERN	400	1	1010	51%	51%	111%	110%
3	MORALEJA	400	S.FERNAN	400	1	780	59%	61%	110%	113%
3	ASOMADA	400	CARRIL	400	1	880	81%	86%	110%	117%
8	VANDELLO	400	CAMARLES	400	1	1380	58%	56%	110%	106%
8	ESPARTAL	220	MONTETOR	220	1	260	58%	56%	110%	107%
3	BIENVENI	400	BROVALES	400	1	1270	45%	46%	110%	113%
3	CARTUJOS	220	MONTETOR	220	1	360	67%	67%	110%	110%
3	COSLADAB	220	LOECHESB	220	1	360	80%	80%	110%	110%
7	CARROYUE	220	ARSNJUA	220	1	630	74%	75%	110%	113%
8	L.MONTES	220	LOSRAMOS	220	1	210	52%	39%	110%	85%
6	BSONUEVO	220	VILANOVA	220	1	400	64%	64%	110%	110%
8	ALDAIA	220	QUARTPOB	220	1	430	49%	47%	110%	105%
3	QUINTOS	220	S.ELVIRA	220	1	441	80%	80%	109%	104%
8	MEQUINEN	400	MAIALS	400	1	820	77%	76%	109%	108%
6	CENTELLE	220	CERCS	220	1	220	2%	1%	109%	108%
3	RICOBAYO	220	VILLARIN	220	1	490	65%	68%	109%	113%
3	LA ROBLA	400	VILLAMEC	400	1	930	55%	55%	109%	111%
3	MUDARRIT	220	TMUDI2	220	2	360	55%	56%	109%	112%
3	ARAGON	400	ARNERO	400	1	1300	79%	80%	109%	110%
6	PQINGENI	220	VILLAV B	220	2	400	62%	61%	109%	107%

6	JALON	220	PLAZA	220	1	330	57%	55%	109%	106%
3	BESCANO	400	LLOGAIA	400	1	2030	54%	54%	108%	108%
3	LLOGAIA	400	LAFARGA	400	1	2030	54%	54%	108%	108%
3	MAJADAHO	220	TALAVERA	220	1	410	83%	85%	108%	111%
3	BOADILLA	220	VILLAV_B	220	1	280	68%	69%	108%	110%
3	MATA	220	TANGCATA	220	1	400	65%	65%	108%	108%
3	TORRIJOS	220	TVELASCB	220	1	320	72%	74%	108%	111%
3	MUDARRA	400	LUENGOS	400	1	820	82%	84%	108%	110%
3	LA ROBLA	400	MUDARRA	400	1	820	82%	84%	108%	110%
3	GUADAME	220	OLIVARES	220	1	170	21%	21%	108%	105%
3	MAJADAHO	220	VILLAV_B	220	1	280	65%	66%	108%	109%
3	LA JARA	220	TAYALA2	220	1	330	67%	67%	107%	107%
3	GRIJOTA	400	VILLARIN	400	2	910	83%	85%	107%	111%
8	ESCATROB	220	HIJAR	220	1	210	53%	53%	107%	107%
8	PINTO	220	TVELASCA	220	1	480	63%	62%	107%	105%
3	PENARRUB	400	PINILLA	400	1	1470	70%	71%	107%	108%
6	PQINGENI	220	VILLAV B	220	1	400	53%	52%	107%	105%
3	LA ROBLA	400	LUENGOS	400	1	820	81%	83%	107%	109%
3	GATICA	400	GUENES	400	1	1590	87%	87%	106%	107%
3	MANFIGUE	220	C.JARDIB	220	1	240	53%	53%	106%	106%
1	CANYET	220	GRAMANTB	220	1	350	53%	53%	106%	106%
3	QUINTOS	220	DRODRI_B	220	1	170	9%	20%	106%	108%
3	CAMPONAC	220	HORTALEZ	220	1	440	22%	22%	106%	107%
8	ROCAMORA	400	STA ANNA	400	1	1440	72%	69%	106%	102%
3	TORSEGRE	220	MEQUINEN	220	1	600	78%	78%	106%	106%
8	PINTO	220	VILLAVER	220	1	350	45%	44%	106%	103%
4	CARTELLE	220	CASTRELO	220	2	230	40%	37%	106%	99%
8	ESCATROB	220	VILLANUE	220	1	210	67%	67%	106%	105%
8	ESCATROB	220	VILLANUE	220	2	210	67%	67%	106%	105%
3	EALMARAZ	220	TORREJON	220	1	240	56%	56%	106%	107%
3	EALMARAZ	220	EBORA	220	1	400	77%	78%	106%	108%
8	GARRAF	400	VANDELLO	400	1	980	80%	79%	106%	105%
8	PALMERAL	220	ALICANTE	220	1	417	79%	76%	106%	102%
8	CANTALAR	220	MTEBELLO	220	1	360	65%	63%	106%	103%
8	C.JARDIB	220	CODONYER	220	1	240	62%	62%	105%	105%
8	JIJONA	220	VILLAJOY	220	1	360	65%	64%	105%	103%
3	GRIJOTA	400	VILLARIN	400	1	910	81%	83%	105%	108%
3	LA PLANA	220	SERRALLO	220	1	320	62%	63%	105%	107%
8	ARANUELO	400	VALDECAB	400	1	1280	67%	62%	105%	97%
8	ARANUELO	400	VALDECAB	400	2	1280	67%	62%	105%	97%
8	PRADILLO	220	TVELASCA	220	1	545	54%	53%	105%	103%
3	ORCOYEN	220	TAFALLA	220	1	560	48%	48%	105%	104%
3	PALMAR1	220	PALMAR	220	1	630	61%	62%	105%	106%
3	ICHASO	220	ELGE_NP	220	1	320	38%	38%	105%	106%
8	ALMARAZ	220	EALMARAZ	220	1	350	47%	44%	105%	99%

3	PEREDA	220	SOTORIBE	220	1	250	88%	88%	105%	106%
1	REBORIA	220	GOZON	220	1	530	67%	67%	105%	105%
3	OLIVARES	220	MAZUELOS	220	1	259	57%	55%	104%	105%
3	PRADSANT	220	VILLAV_B	220	1	360	37%	38%	104%	107%
3	CAMPOAMO	220	BALSICAS	220	1	490	48%	49%	104%	107%
3	LLAVORSI	220	LA POBLA	220	1	410	81%	82%	104%	105%
8	HERRERA	400	LORA	400	1	990	75%	73%	104%	101%
3	ALBATARR	220	TORSEGRE	220	1	600	76%	76%	104%	104%
3	BENAHADU	220	BERJA	220	1	350	59%	53%	104%	100%
3	PIEROLA	220	C.JARDIB	220	1	550	88%	88%	104%	104%
8	ALDEADAV	400	VILLARIN	400	1	1510	67%	63%	104%	99%
8	AYORA	400	CAMPANAR	400	1	1790	80%	78%	103%	100%
5	GRAMANET	400	PIEROLA	400	1	940	68%	68%	103%	104%
8	ARAGON	400	PENAFLOR	400	1	1340	67%	66%	103%	102%
1	R.CALDES	220	S.FOST	220	1	530	88%	88%	103%	103%
3	GETAFE	220	COSLADAB	220	1	315	70%	69%	103%	103%
4	SABINANI	220	TESCALON	220	1	320	66%	67%	103%	103%
5	S.ANDREU	220	TRINITAT	220	1	414	56%	56%	103%	103%
6	MONTETOR	220	PLAZA	220	1	330	52%	51%	103%	101%
3	PALENCIA	220	TMUDI2	220	1	540	76%	78%	103%	105%
6	BSONUEVO	220	GRAMANTA	220	3	450	64%	64%	103%	103%
3	RIBARROJ	220	ARNERO	220	1	210	27%	26%	103%	103%
8	C.COLON	220	ONUBA	220	1	320	57%	57%	102%	103%
3	BEGUES	220	GAVARROT	220	1	350	53%	53%	102%	102%
3	CACERES	220	TORREJON	220	1	240	52%	53%	102%	104%
3	TVELASCB	220	VILLAVER	220	1	480	57%	58%	102%	104%
6	BEGUES	220	GAVARROT	220	2	360	68%	68%	102%	102%
8	ARGANDA	220	VALDMORO	220	1	350	61%	58%	102%	97%
8	ELIANA	220	QUARTPOB	220	1	430	42%	39%	102%	98%
5	BSONUEVO	220	GRAMANTA	220	2	414	63%	63%	102%	102%
3	RUBI	220	TCELSA	220	1	430	70%	70%	102%	102%
3	BESCANO	400	LAFARGA	400	1	2030	53%	53%	101%	101%
3	GUILLENA	400	VALDECAB	400	1	700	46%	50%	101%	110%
8	S.BOI	220	GAVARROT	220	1	350	58%	58%	101%	101%
7	MEDIODIA	220	MAZARRED	220	1	485	60%	62%	101%	105%
8	TVELASCO	400	VILLAVIC	400	1	780	22%	22%	101%	98%
3	ADRALL	220	LLAVORSI	220	1	410	78%	78%	101%	101%
6	BSONUEVO	220	TANGCATA	220	1	400	66%	66%	101%	101%
6	MATA	220	VILANOVA	220	1	400	35%	35%	101%	101%
3	AVEZARAG	220	PENAFLOR	220	1	360	36%	35%	101%	101%
3	GRADO	400	GOZON	400	1	1090	58%	59%	101%	102%
3	COMPOSTI	400	VILLAMEC	400	1	900	45%	45%	101%	103%
7	AGUACATE	220	PQINGENI	220	1	470	60%	61%	101%	101%
3	VILLALCA	220	VILLARIN	220	1	304	69%	71%	100%	104%
3	VILLALCA	220	VILLARIN	220	2	304	69%	71%	100%	104%

8	VITORIA	400	BRIVIESC	400	1	950	81%	79%	100%	98%
2	TIBO	220	TOMEZA	220	1	380	58%	55%	101%	96%
3	LA ROBLA	400	SOTORIBE	400	1	1080	63%	64%	100%	102%
4	AYORA	400	BENEJAMA	400	1	1100	54%	53%	100%	97%
3	MUDARRA	400	SS REYES	400	1	910	72%	74%	100%	103%

Maximum overload 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 [%]
3	SINES	400	PEGOES	400	1	1321	108%	111%	171%	175%
3	PALMELA	400	SINES	400	2	1321	93%	95%	162%	166%
3	F.ALENT	400	SINES	400	2	1361	110%	113%	140%	144%
3	SINES	150	M.PEDRA	150	1	191	95%	97%	139%	143%
3	PALMELA	150	PMMP/PE	150	1	191	93%	95%	138%	141%
3	M.PEDRA	150	PMMP/PE	150	1	191	93%	95%	138%	141%
3	F.ALENT	400	ALQUEVA	400	1	1361	69%	71%	113%	117%
3	F.ALENT	150	EVORA	150	1	218	81%	83%	111%	113%
3	PALMELA	400	ALCOCHET	400	1	1321	77%	79%	110%	112%
3	FANHÕES	400	ALCOCHET	400	1	1321	74%	76%	107%	110%
3	F.ALENT	150	ERMIDAS	150	1	260	36%	37%	102%	105%
3	SINES	150	ERMIDAS	150	1	260	35%	35%	101%	103%

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