



and northern Mediterranean, and even northern Europe. Having this in mind, this interconnection was studied under the umbrella of Med-TSO, promoted by REN and ONEE.

Therefore, the main driver of the project is to further increase the interconnection capacity between Mediterranean Countries, namely between Portugal and Morocco (without any interconnection between these two countries until now), in order to exploit the complementary characteristics of both countries.

Promoted by REN and ONEE under the umbrella of Med-TSO studies.

4.3.2.2 Assessment of reinforcements

Network studies performed by Med-TSO evaluated the internal grid reinforcements needed to accommodate 1000 MW of exchange in both directions between Morocco and Portugal and specified the best technologies to be used in this interconnection.

The security analysis performed with the merged full models of the systems of Portugal, Morocco, Algeria and Spain for 8 PiTs selected identified the reinforcements in Portugal, Morocco and Spain, while no reinforcement was detected in Algeria.

Algeria

No remarkable overloads associated to the new interconnection MAPT were identified in the Algerian system, thus no reinforcements are supposed to be needed for Algeria.

It is worth mentioning that the N-1 contingency of a new 1000 MW 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 1000 MW nuclear plant trip.

Morocco

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

- Two new 400 kV OHL of 220 km between substations DAR.CHAOUL40 and SEHOUL_400
- A new 400 kV OHL of 20 km between substations DAR.CHAOUL40 and MELOUSSA400
- A new 225 kV OHL of 19 km between substations MELOUSSA225 and TANGERI225
- A new 600 MVA transformer between substations SEHOUL_400 and ESSAHOUIRA-22 and the upgrade of the two existing ones from 450MVA to 600MVA

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

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

Portugal

The following internal reinforcements in Portugal were identified in order to accommodate the power flow between Portugal and Morocco (1000 MW). Therefore, two main corridors are to be reinforced to cope with such a transit, as it is shown in next figure:

- **Upgrading for double circuit of OHL F.Alentejo – Tavira (400kV+150kV):** currently, this corridor just contains only a 150 kV OHL. So, the reinforcements involve upgrading this actual corridor to a 400kV+150kV double circuit line;
- **2nd circuit of double OHL Tavira (PT) – Puebla de Guzman (ES):** this double circuit OHL currently comprises only one circuit and needs to be upgraded to a full double circuit line (installation of the 2nd circuit in this interconnection). This reinforcement was identified by both TSOs (REN and REE) according the results of this Med-TSO study.



Therefore, the total network investment costs in the Portuguese grid is around **69 M€**.

Spain

The Spanish system is affected by the interconnection MAPT project mainly in the 220 kV network. The security analysis was based on a differential analysis (i.e. the differences in overloads with and without the MAPT project) due to the high overloads identified in the Spanish network in the N situation. This analysis consisted on the N, N-1 and N-2 contingency simulation with the MA-PT project and without the MA-PT project. Redispatch of generation according to Market Studies was taken into account to obtain equivalent PiTs without the MAPT project.

The simulations showed the occurrence of internal overloads in Spain that can be associated to the Spanish generation mix in 2030. Overloads in internal lines in Portugal and in tie lines across the border (between FALAGEIRA-CEDILLO and ALQUEVA-BROVALES) are evident as well.

The differential analysis for all PiTs has shown that only 4 circuits have an increase in the overload with the MAPT project of more than a threshold of 15% chosen for determining concrete reinforcements if the additional overloads are higher than that. Hence, it is understood that these concrete lines will need to be reinforced due to the MAPT project. It is foreseen that a simple substitution of conductors in the follows OHL to increase the ampacity is sufficient since the maximum increase in flow observed for all the overloaded lines is less than 30% of the rate.

- TRUJILLO - MERIDA 220kV
- TRUJILLO - ALMARAZ 220kV
- ALVARADO – BALBOA 220kV
- GUILLENA_B - CENTENARIO_NPB 220kV

Bearing in mind the reinforcements mentioned, it is estimated that the cost of the reinforcements in Spain in the 220 kV network is around 22 M€. It is also necessary to include the cost of 4 M€ corresponding to upgrade of the OHL between Tavira (PT) – Puebla de Guzman (ES) 400 kV (i.e., the installation of the 2nd circuit). The estimate of the total investment cost in Spain due to the MAPT project by the CON is **26 M€**.

In addition, a complementary analysis was performed to evaluate other generic reinforcements that being overloaded without the project, become significantly more overloaded (at least 5%) in the case with the MAPT project. The estimate of this investment cost is around 7.5 M€

On top of this analysis carried out by REE, it is also necessary to include the cost of 4 M€ corresponding to upgrade of the OHL between Tavira (PT)–Puebla de Guzman (ES) 400kV (installation of the 2nd circuit) as well. The estimate of the total investment cost in Spain due to the MAPT project by REE is, therefore, 33.5 M€ (22 M€ of concrete reinforcements plus 4 M€ for the second circuit of Tavira – Puebla de Guzman plus 7.5 M€ of additional reinforcements).

Finally, for the purpose of the Mediterranean Master Plan (MMP) it can be concluded that the costs for internal reinforcements in Spain is in the range of **26M€ - 33.5M€**.

The cost of above mentioned internal reinforcements is presented in the table below, together with the investment cost of the new interconnection. The overall investment cost of the project ranges between 657 and 724M€.

4.3.3 ■ Project 2 Morocco – Spain (MAES)

Detailed description is provided in [14]

4.3.3.1 *Project description and data acquisition*

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

The HVAC interconnection will have a capacity of 1000MW and a total length of around 70 km corresponding 30 km to the length of the undersea cable and the rest to overhead lines in Morocco (30 km) and Spain (10 km) to connect with the existing 400 kV grid.



The HVAC link consider a configuration of 1000 MW circuit, between TARIFA substation of 400 kV (ES) and BENI HARCHAN substation of 400 kV (MA).

The interconnection project favours the use of the most efficient capacity in the PAN European interconnected system. The project also increases the system operational flexibility. Such benefits are ensured according to different future scenarios.

Promoted by: ONEE and REE (under the umbrella of the studies carried out by Med-TSO within the Mediterranean Project I).

The models adopted for project MAES is described in 4.3.1.1 being in common with projects 1 and 3.

4.3.3.2 Assessment of reinforcements

Algeria No remarkable overloads associated to the new interconnection were identified in the Algerian system, thus no reinforcements were defined for Algeria.

It is worth mentioning that the N-1 contingency of a 1000 MW 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 1000 MW nuclear plant trip.

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

- Two new 400kV OHL of 220 km between substations DARCHAOU40 and SEHOUL_400
- A new 400kV OHL of 20 km between substations DAR.CHAOU40 and MELOUSSA400
- A new 225kV OHL of 19 km between substations MELOUSSA225 and TANGERI225
- A new 600 MVA transformer between substations SEHOUL_400 and ESSAHOUIRA22 and the upgrade of the two existing ones from 450 MVA to 600 MVA.

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

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

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

The calculations have shown overloads in the Spanish grid also in N conditions. Hence a “differential analysis” has been performed, i.e. the security assessment with the MAES project and without the MAES project. Redispatch of generation according to Market Studies was taken into account to obtain equivalent PiTs without the MAES project.



The simulations showed that without the MAES project several internal overloads in Spain appear. Some overloads also appeared in the tie lines FALAGEIRA-CEDILLO and ALQUEVA-BROVALES, between Portugal and Spain.

Nevertheless, bearing in mind the abovementioned approximations and taking into account that the differential analysis highlighted an increase in the overload with the MAES project of more than the 15%, it is advisable to reinforce the lines in Table 2. Reconductoring interventions are also considered sufficient for the lines with an overflow 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	LOS RAMOS	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	DOSHNAS	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 2 – Circuits identified in Spain for reinforcement in order to accommodate the 1000 MW flow between Spain and Morocco (Med-TSO network studies)

The estimate of the investment cost in the lines identified in Table 2 is around 33 M€. Finally, the total investment cost for the reinforcements in Spain calculated with the above analysis is $33 + 144 = 177$ M€.

In addition, a complementary analysis was performed to evaluate other generic reinforcements that being overloaded without the project, become significantly more overloaded (between 5% and 15%) in the case with the MAES project. The estimate of this investment cost is around 17 M€

Therefore, the estimate of the total investment cost in Spain due to the MAES project is **194 M€**.

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

Portugal The overloads identified in the Portuguese system were associated to the aforementioned general scenario in Spain. Therefore, no concrete reinforcements have been defined for Portugal. The cost of above mentioned internal reinforcements is presented in the table below, together with the investment cost of the new interconnection. The overall investment cost of the project ranges between 397 and 414M€

4.3.4 ■ Project 3 Algeria – Spain (DZES)

Detailed description is provided in [15]

4.3.4.1 Project description and data acquisition

The project consists of 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 will be around 2000m.

Promoted by: SONELGAZ and REE (under the umbrella of the studies carried out by Med-TSO within the Mediterranean Project I).

2 configurations of the HVDC link have been considered:

- single (1x1000 MW) pole converter
- double (2x500MW) pole converter]



The configuration b) was selected for the HVDC link considering 2 circuits of 500 MW each between CARRIL2, new substation of 400 kV (ES) that will be connected to CARRIL 400 kV substation, through a 400 kV OHL double circuit and a substation located in Terga region that will be connected to 400/220 kV substation (AIN FATEH) through two 400 kV OHL of 50 km each (DZ). In this configuration a single and double contingency on the two circuits has been evaluated.

4.3.4.2 Assessment of reinforcements

The following reinforcements are required:

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

Thus, the total cost for internal reinforcements in **Algeria is 74,6 M€.**

It is worth mentioning that the N-1 contingency of a 1000 MW 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 actions in order to mitigate the impact of such contingency, without penalizing the transfer capabilities. Ad hoc studies should be performed to analyse the primary reserve capabilities of the area.

Morocco. No remarkable 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 DZES project in the 220 kV and 400 kV networks. The new DC interconnection will depart from the new 400 kV substation CARRIL2 which is connected to substation CARRIL via a double OHL of 10 km. The following reinforcements were proposed and simulated:

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

These investments are 10 M€ for the rate upgrade of the 220 kV OHL and 19 M€ for the new 400 kV OHL totalling 37 M€.

Other concrete reinforcements (with an estimated cost of 122 M€) are:

- Upgrade from single to double the following OHL:
 - CAMPOAMO - DESF.SMS 220kV
 - ASOMADA – CARRIL 400kV
 - GUADAME – OLIVARES 220kV

- Substitution of conductors to increase the ampacity in the following OHL:

• ELCHE2 - SALADAS 220kV	• NESCOMBR – TREMENDO 400kV	• PALMAR – ROCAMORA 400kV
• ROCAMORA – TREMENDO 400kV	• BENEJAMA – SAX 400kV	• STA ANNA – SAX 400kV
• ROCAMORA - STA ANNA 400kV	• PALMERAL – TORLLANO 220kV	• CABRA – MOLLINA 400kV
• ROCAMORA – ROJALES 220kV	• CAMPOAMO - S.P.PINA 220kV	• CARTAMA – MOLLINA 400kV
• ROJALES – SMSALINN 220kV	• MINGLANI – OLMEDILL 400kV	• LA PLANA – GAUSSA 400kV

In addition, a complementary analysis was performed to evaluate other generic reinforcements that being overloaded without the project, become significantly more overloaded (between 5% and 15%) in the case with the DZES project. The estimate of this investment cost is around 27 M€

Therefore, the estimate of the total investment cost in Spain due to the DZAES project is in the range between 151 M€ and 178 M€.

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

The cost of above mentioned internal reinforcements is presented in the table below, together with the investment cost of the new interconnection. The overall investment cost of the project ranges between 899 and 926M€.