Task 2.1.2

Mediterranean Master Plan of Interconnections

Objective 2030

Outlook of the Task and Deliverables

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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Important Notes:

a) It is not the scope of the MMP 2030 to rank along any criteria the projects described in this document.
b) All Projects have been studied and the conclusions (negative or positive) have been endorsed by the Med-TSO Members. The MMP 2030 has been drafted in full transparency and extensive consultation with all Med-TSO Members.
c) This document aims at linking the deliverables affecting the planning process. It is not part of the set of deliverables prescribed by the contract.

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Recurrent abbreviation

OHL	Overhead Line	Aerial lines
PiT	Point in Time	Hour in the market simulations significant of a given situation (e.g. stress
HVDC	High Voltage Direct Current	
HVAC	High Voltage Alternate Current	
AIS	Air Insulated Substation	
	Reconductoring	Revamping of overhead lines by substituting wires with more performing cords
MMP	Mediterranean Master Plan	Set of documents describing the relevant grid, the interconnection projects and the methodology adopted
MP	Mediterranean Project	Project supported by the EU
BTC	Bilateral Transfer Capacity	Active power of cross-border exchanges agreed between two TSOs

1 The Mediterranean Master Plan 2018

1.1 The Mediterranean Master Plan and its structure

The Mediterranean Master Plan 2030 (MMP 2030), is the Development Plan of the interconnections between 20 Grid Operators Members of Med-TSO. 2030 refers to the time horizon of this plan. MMP2030 defines the feasibility of 14 main interconnection projects (within three corridors) between regional electric systems and the necessary internal reinforcements to guarantee proper security standards.

The MMP 2030 is delivered in the framework of the action plan of the Med-TSO Association and the Mediterranean Project funded by the European Commission (DG NEAR), as better reported later in this document. One of the main targets of Med-TSO, encouraged by the EC, is the harmonization of processes, criteria etc. this target is pursued promoting at the highest priority the cooperation among the Members of the Association. Setting up a master plan aiming at interconnecting the member systems is the most concrete expression of this cooperation and the willingness to share knowledge and information. This cooperation already found a concrete experience in a previous edition of the Master Plan [34-37], briefly called *paving the way.* Although paving the way triggered the Association towards concrete cooperation the MMP2030 is the first master plan built on a systematic application of agreed criteria and analyses as result of massive simulations. Like paving the way MMP2030 is the result of a bottom up approach sustained by Med-TSO Members.

The MMP 2030 is made of several reports ranging from the definition of the planning methodology [1] to the data collection, from the market studies to the network studies and procedures. Most of them are the deliverables of the Mediterranean Project. The complete Bibliography is reported in Cpt 6. This document summarizes the most important conclusions and recalls such reports for further information, but it is not a deliverable prescribed by the contract with the EC. Therefore, in case of contradiction the deliverables prevail on this document.

For a wider vision of the entire Mediterranean Project, we suggest to consult also [47]

This document contains 6 Chapters. Each of them shows the main steps of the process adopted to set up the MMP 2030 aiming at describing both results and basics of the adopted methodologies.

Chapter 1 introduces the matter and sums up the general framework.

Chapter 2 deals with the main ideas behind the initiative of setting up a Master Plan by showing the evolution of the systems on the two shores of the Mediterranean Sea in the next two decades, hence the complementarities of the two shores promising interesting synergies.

Chapter 3 summarizes the scenarios and the market studies. Due to the fact that a significant part of Med-TSO Members are also Members of ENTSO-E, the scenario selection and the methodology adopted in the MMP 2030 cannot ignore the Ten Years Network Development Plan (TYNDP), the scenarios adopted and the methodologies used in the European context. As a consequence the parallelism with the same activities in ENTSO-E is mentioned several times.

Chapter 4 summarizes the 14 projects and the process to pass form the outcomes of the market studies to the network analyses leading to the definition of the cross border connections and the internal network reinforcements. This chapter highlights the value of the MMP2030 in terms of opportunities of investments.

Chapter 5 reaffirms that Master Plans are living studies driven by the continuous evolution of the society, the economy, the technology. Therefore, parallel to the studies Med-TSO developed tools that are needed to guarantee an efficient process.

Chapter 6 briefly depicts the Med-TSO process to issue future Master Plans and what are the targets to improve the quality of the system development process in the Mediterranean Region.

MMP 2030 is the result of about 3 years of activity started with the design and consolidation of the methodology harmonized (and where applicable compliant) with the ENTSO-E practices. A second phase encompassed the application of the agreed methodology and the data acquisition to perform the analyses accordingly. The third phase has been dedicated to the analyses (market and network) to end up with the 14 projects. The same process is meant to be repeated biannually by the Members.

1.2 The mission of Med-TSO and the Mediterranean Project

1.2.1 Med-TSO in a nutshell

Med-TSO is the voluntary Association **of the Mediterranean TSOs[1],** established on 19 April 2012 in Rome. Initially composed of electricity companies from 15 countries of the Mediterranean (Fig. 1), it is now constituted by 20 members from 18 Countries.

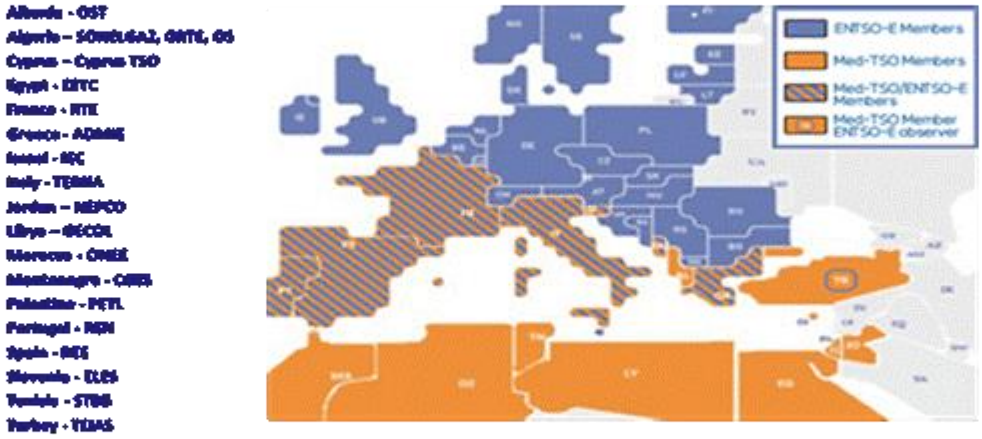

Figure 1. Countries of the Med-TSO Area.

In 2013 Med-TSO started its operational activities, with its first initiative being based on a process of multilateral cooperation for a coordinated planning of interconnections and internal grid developments of each country, which produced the Master Plan of the Mediterranean Interconnections (resulting from the EU-funded project "Paving the Way for the Mediterranean Solar Plan" [34], [35], [36], [37]).

At the same time, in 2013, the rapid and sudden evolution of the energy reference scenario [4], [5] was made obvious, caused by new phenomena. i.e.: i) the structural change in the international fuel market produced from non-conventional fuels, ii) the interference between the production of electricity from renewable sources and that from conventional sources, iii) the reduction of power consumption on the Northern shore of the Mediterranean.

This change of scenario suggested changing the assumptions in grid planning: no longer a strong production of electricity from renewable sources in the South for its export to the North, but a trading system much more articulated and complex, aimed at the integration of electricity and energy systems of the two shores of the Mediterranean.

[1] Transmission System Operators: operators of the electricity grid, whose essential function is to ensure the balance between demand and supply of electricity on the grid, either in real time or in the medium to long term, managing network resources (generation plants and transmission) in accordance with the rules and models of the market.

The management of uncertainty, generated by a change of scenario, drives the priorities of security objectives (supply and electricity service), flexibility (to face the uncertainty of forecasts and of contingent phenomena) and efficiency (to optimize use of resources and minimize costs).

These objectives find a direct confirmation in the benefits of integration, resulting from operating resources (primary energy sources, power generation plants, etc.), in a co-ordinated way with less costs and risks of investment in infrastructure. These benefits turn out to improve security (availability of resources), efficiency (optimal use) and flexibility (the network operating according to requirements).

According to these concepts, Med-TSO's primary goal is to investigate possible transmission infrastructure projects and preliminarily quantify the costs of the HV grid development in the Mediterranean Region [2].

During the reference period (2016-2030), the TSOs foresee an increase in the generation capacity in the Mediterranean Countries of approximately **250 to 400 GW** (Table 3), of which 40 to 60% from renewable energy sources[2] (RES), corresponding to an expected increase in electricity demand of about 800 to 1100 TWh (Table 2).

Investments in new production capacity, according to the generation mix, amount approximately to 600 billion EURO[3] in the next 15 years.

In these cases, the priority today is the strengthening and integration of networks on the Southern shores of the Mediterranean, as a condition for their integration with the networks of the Northern shore.

1.2.2 MED-TSO's Action Plan for 2015-2017 - The Mediterranean Project

Based on the experience in 2013, Med-TSO's Action Plan for 2015-2017, oriented to support infrastructural projects, is developed according to the following five axes.

1.2.2.1 Common Set of Rules for a Mediterranean Power System and Transmission Grid Code

The overall objective of this Task is to develop and share a minimal and common set of basic rules for the Mediterranean interconnected power systems. These rules range from operation to the connection of users, able to consent the exchanges of electricity among interconnected grids and the development of the power system facilities (in generation and transmission), while contributing to institutional cooperation in the TSOs functions.

1.2.2.2 Planning and development of the Euro-Mediterranean Electricity Reference Grid

To plan and develop the Euro-Mediterranean Electricity Reference Grid, through studies and specific tools for the coordinated development of interconnections.

1.2.2.3 International Electricity Exchanges

To promote the development of a Mediterranean Electricity System, within a common vision of change in the Mediterranean. This task will focus on methodologies, procedures and mechanisms for sharing resources through cross border exchanges, based on inter-grid complementarities and efficient use of generation infrastructures, allowed by the interconnection of the grids.

1.2.2.4 Knowledge network

Because the human resource is a priority for the development of a new culture, able to activate new development processes, the plan includes the development of a network and a forum of knowledge sharing among the relevant professionals working in the fields related to the scope of the project.

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[2] Percentage that grows up to 65% because of the new hydroelectric capacity mainly foreseen in Turkey.

[3] The variability of the appraisal is due to the uncertainty on the reference scenario and hence on the choices of the operators.

1.2.2.5 Med-TSO's Database

Management of the shared information for the development of power exchanges at regional level, such as characteristic data of the grids and infrastructures, market information (ongoing projects and projects to be defined), rules and procedures.

The Mediterranean Project, structured at a local level, requires multilateral cooperation, not only among electricity companies but also between institutions (National Institutions, Regulators and IFIs) and companies.

1.2.3 Med-TSO organization

The activities of Med-TSO are performed through the contribution of the Members within the Working Groups and Technical Committees.

The work is set in a matrix scheme, based on geographical or thematic issues (i.e. technical, regulatory, economic and financial issues) crossing the following lines of activities of a TSO: Planning, Operation, Electricity Exchanges.

The following summarizes the general organizational scheme.

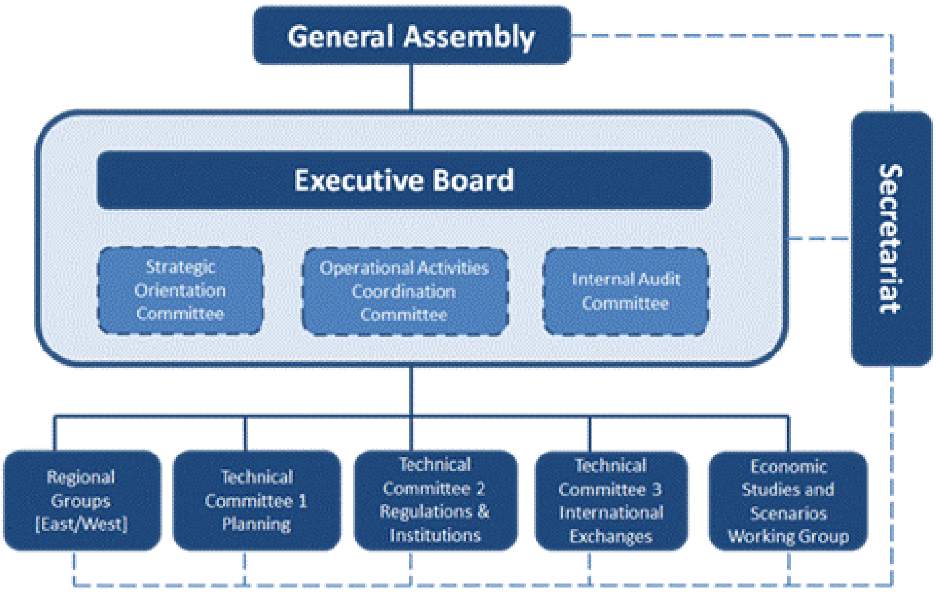

Figure. 2. Med-TSO Organization Chart.

The MMP2030 is the result of cooperation of Technical Committee Planning and the WG Economic Studies and Scenarios. The Technical Committee 3 International Exchanges contributed in the Cost Benefit Analysis calculations. Secretariat contributed to the implementation of the grid map in cooperation with ENTSO-E.

1.2.4 The cooperation with ENTSO-E

The cooperation with ENTSO-E deserves a special mention. Several factors reinforce the cooperation with ENTSO-E:

- A large part of Med-TSO Members is also ENTSO-E Members. Different approaches on the development of the same grids would be inefficient
- The same TSOs have to comply with the EU legislation and regulation. ENTSO as institution plays a role in this context

- ENTSO-E gained experience as Association in rising consensus in matter of harmonization. It would be inefficient ignore these facts and restart from scratch
- ENTSO-E and Med-TSO share the same objective of setting up regulation for the stability of the energy sector and for the benefit of the society.

Nevertheless, Med-TSO has a different governance background and harmonization does not necessarily imply the imposition of the same rules. In this context, unanimity is an important way of reach consensus on common principles.

1.3 A Grant Contract to implement the Mediterranean Project

The Euro-Mediterranean Region is a community of about a billion people, whose integration is no longer just an opportunity, but an unavoidable requirement: to ensure a common future, safer and healthier for all populations of the Southern as well as the Northern shore, and especially for the new generations. Due to the awareness that security objectives, sharing of prosperity, stability and civil cohabitation can only be pursued through a joint effort, many Mediterranean countries have demonstrated willingness for multilateral cooperation.

At the same time, in Europe, the symptoms of a crisis have deepened which no longer has just financial traits but is also characterized by structural elements. The crisis has several causes that stem from the past: the social structure is changing, because of a progressive aging population in the Northern Mediterranean Countries (and related social problems), decreasing (or stagnation) of consumptions. The Southern shore is affected by phenomena of economic growth, although discontinuous, young population and increasing of consumptions.

The phenomena taking place in the Mediterranean area show important elements of complementarities.

The job-related problems are severe on both shores, despite their differences, and in both cases, fear for the future constitute a brake to development. Job constitutes also a common opportunity for both sides of the Mediterranean: it is a precious element for emancipation, identity and dignity, as grounds for a new common and multi-ethnic culture.

The Mediterranean Project promotes the creation of jobs through the expansion of infrastructures, taking into consideration that the development of basic infrastructures (energy, water, transport) is the requirement for the social and economic development.

Energy plays a vital role for the security of the Mediterranean countries and no significant economy progresses can be imagined in modern societies without the support of reliable energy.

1.3.1 Ongoing transformation of the Euro Mediterranean energy scenario

1.3.1.1 Gas spot market

The creation of the gas spot market, resulting from the commercial operation of the so-called shale gas, has changed the primary energy sources market, opening to more competitive scenarios, in terms of both volumes and prices.

In addition, the recently discovered gas fields in the South-eastern Mediterranean region open new perspectives, driving towards a possible general transformation of the economic and productive equilibrium at a Euro Mediterranean level.

1.3.1.2 The organized electricity market that, in the current form, is not reflecting a process of economically efficient pricing mechanism.

The introduction of renewable energy sources (RES) energy on the market, at administrated prices and for relevant volumes, has conditioned the capacity of the market to remunerate investments[4] and the security of the electricity service[5], especially on the eve of the unification of the internal European Market (market coupling) which should require:

a. Structural balance of the different markets to be coupled
b. Congruent planning of incentives and rules for the production of RES energy
c. Appropriate market mechanisms and products
d. Appropriate interconnection level of the national energy and electricity systems

1.3.1.3 The contraction of the energy demand

There are differences in the energy demand in the main countries of the Northern shore and the growth in the countries of the Southern shore, limited only by phenomena of instability and uncertainty in most of these countries.

1.3.1.4 Conclusions

This is not a transitory phenomenon, but symptomatic of a current structural change. A tumultuous evolution that, if not governed, can generate unquantifiable risks.

In this situation:

- The Euro Mediterranean area globally has the resources (knowledge and primary energy sources) to support the regional development.
- The slackening of constraints and the vaporization of complementarities constitute a must: integration of energy systems, through converging rules and interconnection infrastructure.
- Gas and RES will characterize the future regional energy scenario, and therefore a growing demand for flexibility, security and efficiency, will arise. This will require new regulation at regional level.

1.3.2 Towards regional policies for infrastructure development

The Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committees and the Committee of the Regions (Brussels, 14 October 2013), concerning the long-term vision for energy infrastructures in Europe and beyond its borders, testifies this value.

Adequate electricity infrastructures, integrated and efficient, constitute the basis for the achievement of development and security goals.

The creation of security, stability and prosperity, shared at a regional level, represents a common objective of the Mediterranean countries, which can only be achieved with a global approach, therefore including all the countries and factors, which determine it.

A politics of multilateral cooperation, following a “bottom-up” approach, able to improve complementarities: a global response to ongoing changes in the Mediterranean.

In this context, the European Commission acknowledged the Med-TSO platform as an efficient cooperation instrument. A platform, which has, allows identifying and analysing potential infrastructure projects, as stated in the Memorandum of Understanding Med TSO - MEDREG – EC, signed in Rome on 18th November 2014.

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4 An example.: in Italy in 2013 there were prices at peak times even lower than at night, while in Spain they even recorded rates near zero for several periods

5 Insufficient « rotating » reserve capacity (the one immediately available in case of need, such as the one delivered by the production plants already operational and connected to the grid) during periods of maximum production from RES.

1.3.3 The Grant Contract[6]

A 3 years Contract has been signed on 30 December 2014 between the European Commission and Med-TSO Association through the GRANT CONTRACT - External Actions of the European Union - ENI/2014/347-006 [47], with the overall objective to extend and integrate the Mediterranean electricity markets [19]. To reach it a specific objective was assigned to Med-TSO, i.e. to set up common standards and rules in order to facilitate the Integration of the Mediterranean Power Systems.

The Contract defined more precisely the Expected results in:

R1: Common Set of Rules for a Mediterranean Power System and Transmission Grid Code
R2: Euro-Mediterranean Reference Grid
R3: International Electricity Exchanges
R4: Increased capacity of TSO personnel
R5: Med-TSO database
R6: Increased visibility.

The main results of R2and R5 are summarised in this document.

1.4 A short summary of the process for setting up the MMP 2030

To make easier the comprehension of how the MMP 2030 has been built up one should bear in mind that in the spirit of the harmonization and the Mediterranean Project there are two main goals:

a) To issue any MMP as a result of a cooperative and consolidated process
b) To set up a sustainable way of working that can be reiterated periodically in a more and more strict coordination with the National Development Plans [3].

To that purpose, the MMP 2030 has been worked out after a thorough analysis dedicated to:

i. the assessment of tools and practices adopted by Members TSOs
ii. the agreement on methodologies to follow
iii. the translation of the abovementioned conclusions in a procedure (a workflow) to keep the MMP updated every two years.

Then the MMP has been divided into 3 basic macro steps [1-3]

1. the market studies
2. the network studies
3. the cost benefit analysis

In parallel and thinking of the sustainability of the process, the DBMED[7] (i.e. the database for Mediterranean) [41], [42], [43], [44] has been developed and a map of the entire basin has been designed and defied.

The present report follows the same sequence of the Macro steps. Before entering the description of the results, Chapter 2 reminds the basic ideas and reasons on why northern and southern banks are considered in the framework of the Mediterranean Project and of the current MMP 2030.

The MMP will be updated on biannual basis, as a basic process of Med-TSO.

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[6] Mediterranean Project (The Action) Grant Contract – External Actions of the European Union – ENI/2014/347-006
[7] DBMED stands for Data Base for the Mediterranean

2 Complementarities between the Southern and Northern banks of the Mediterranean Basin

2.1 Complementarities around the Mediterranean Basin

Trends towards more complementarities around the Mediterranean Region are confirmed by the National Development Plans [45], which are taken as the main initial reference in building the Mediterranean Master Plan.

The worldwide Energy transition and the evolution of the Energy Sectors involve the Northern and Southern [8]banks of the Mediterranean basin in the same direction but with different particularities.

The Northern bank is engaged in ambitious GHG reduction targets and market integration within a general stagnation of the electricity demand.

The Southern bank is characterized by large potential of generation, including but not only renewable energy, and by a rather high rate of growth of the demand, supported by concrete examples of programmes for deployment of RES, while markets are still in evolution.

Complementarities have thoroughly analysed in [6] by WGESS. In a first STEP hourly curve for both load and generation, data from Med-TSO Members have been gathered and in the second step, results from the market study have been added.

2.2 Demand Forecast and complementarities

Since electricity loads depend on many factors among which temperatures, day/night cycle and also people habits, all of these parameters vary significantly between North and South, as well as East and West within the Mediterranean area and in consequence, they offer synergy opportunities. As reported in [6], these complementarities appear at any time interval of the year.

At annual level both load duration curve and load factor [9]can give a preliminary idea about power fleet utilization. The higher the load factor, the better the utilization of power fleet.

For instance, the normalized load duration curves for Turkey and Tunisia[10] compared to whole Med-TSO area in some scenarios show that the load curve for the whole area is even better than the best of the two.

Besides the Load factor is 50% for Tunisia and 70% for Turkey. For the Med-TSO area, the load factor reaches 75%. In other words, and taking into account that load curves with high load factors are better, we can say that the global load curve is better than single country ones, even better than the best single country load curve.

The global load duration curve shows that the minimum annual load for the whole Med-TSO area never goes under 50% of annual peak load, while it goes until 30% for Tunisia and 38% for Turkey.

Most of such findings lie on the fact that there is not a synchronous single country peak and off-peak loads. For instance while Portugal, Albania, France and Montenegro expect the peak load in winter between December and February, many of the other countries register their peak load in summertime.

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[8] Northern and Southern banks are purely conceptual.
[9] LF=Annual Energy $_{MWh}$/(Peak Load $_{MW}$ * 8760$_{hours}$)

[10] These two countries have been chosen only for illustrative purpose because they have the higher (Turkey) and the lower (Tunisia) annual load factors

When summing all the load curves, the obtained global peak load is very different from the sum of national peak loads. The next table shows a comparison between the obtained values for Scenarios 1 and 4 [11] [4], [5].

Peak load (GW)	Scenario 1	Scenario 4
Self-sufficient	440 GW	481 GW
Copper-plate	380 GW	414 GW
Difference	*60 GW*	*67 GW*

Table 1. Comparison between the peak load [GW] values for Scenarios 1 and 4.

An interesting finding is that considering the whole Med-TSO load instead of single country loads, results in a benefit of 60 GW in scenario 1 and 67 GW in scenario 4. Mutualizing the annual complementarity within the Med-TSO Power System area is around 15% of the sum of all national needs seasonality of Demand.

At seasonal level The Mediterranean area is a very large zone that covers countries with very different weathers.
The northern area is characterized by low temperatures while in the southern bank temperatures are quite high. Consequently, we obviously expect annual demand to depend on this parameter and follow its pattern. This reflect on monthly behaviour of the load. [6] Shows that the resulting Med-TSO monthly load has two peaks in January and July and, two off-peaks in April and October.

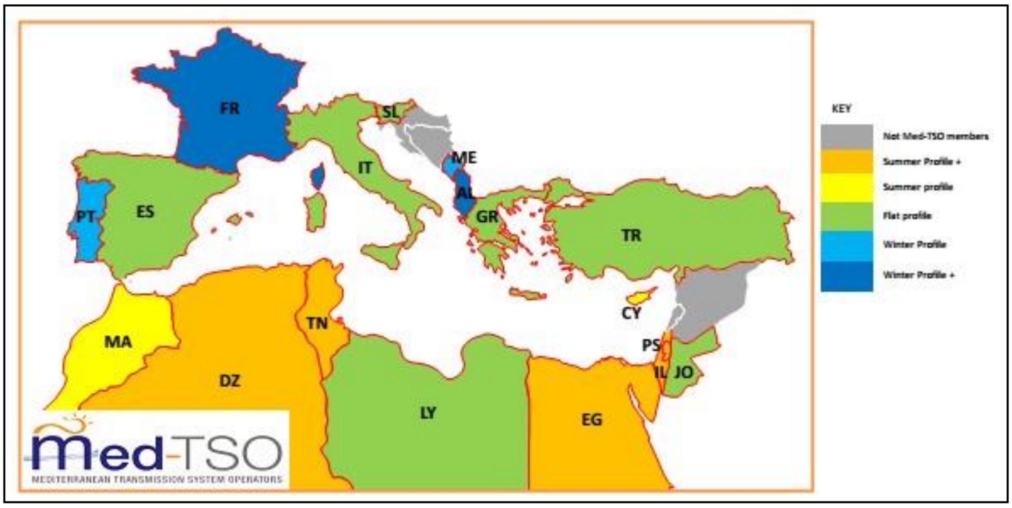


Figure 3. Map of Mediterranean countries depending on annual profile.

At weekly level The weekly complementarity relates to the effect of different holidays and different working days in countries within the Mediterranean Region. In fact, the weekend takes place on Saturday-Sunday in a majority of countries and on Friday-Saturday on some others. This means that these days with low load level will be shifted according to countries.

The analysis of data provided by member countries deserves further attention to be better characterized.

At hourly level Based on previous findings, the objective of this analysis is to determine at an hourly scale, the synergy between Med-TSO members when it comes to load curves. Since the number of countries is too high to permit an illustrative and clear analysis, we choose to divide the area into three corridors:

[11] Scenarios will be dealt later in the document. Scenarios are not forecasts but plausible future environments where power systems could evolve. As better explained in chapter 3

Western corridor, Central corridor and Eastern corridor. Comparison between individual and global loads will be made within each corridor.

For those illustrations, the Western Corridor contains Spain, Portugal, Morocco and Algeria, while the central corridor contains Italy, Algeria, Tunisia and Libya and, finally, the Eastern Corridor considers Albania, Cyprus, Greece, Montenegro and Turkey.

The following figures show, for the three corridors, normalized (to annual peak load) hourly loads for June 4th 2030 Scenario 1.

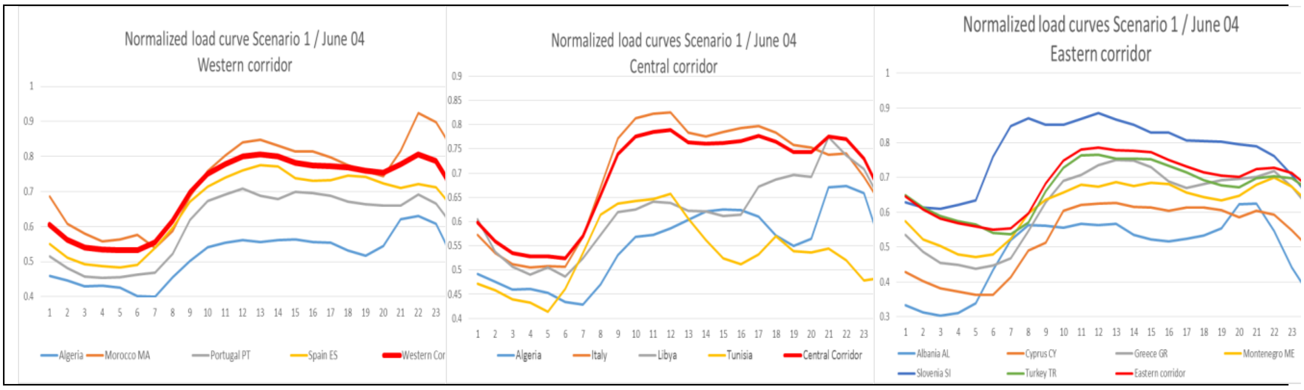


Figure. 4. Normalized (to annual peak load) hourly loads for Scenario 1.

As shown in all of the figures, two profiles can be noticed: evening peak load and mid-day peak load profiles. Regarding aggregated load curve, and for all corridors, two effects can be noticed. The first effect is a higher off peak level and the second one is a relatively flat load curve for most part of the day. This aggregation effect is recurrent in all scenarios.

On the Hourly residual load curves. The residual load curve is the remaining load after deducting renewable generation from demand load curve. Even though demand synergy analysis is very important, it can be noticed that the real synergy is about residual demand. In fact, being a non-dispatchable resource, renewable generation is considered by TSOs the equivalent to a negative load.

A paradigm change in energy system design tools, energy market, and energy policy is required to attain the target levels in renewable energy integration and in minimizing pollutant emissions in power generation. Integrating not-dispatchable [12]renewable energy sources such as solar and wind energy is vital in this context.

The present analysis was made keeping the same corridors as considered before. The following figures illustrate, for these three corridors, individual and global residual load curves for a typical day in Scenario 1 (16 June 2030).

[12] Not dispatchable are the resources

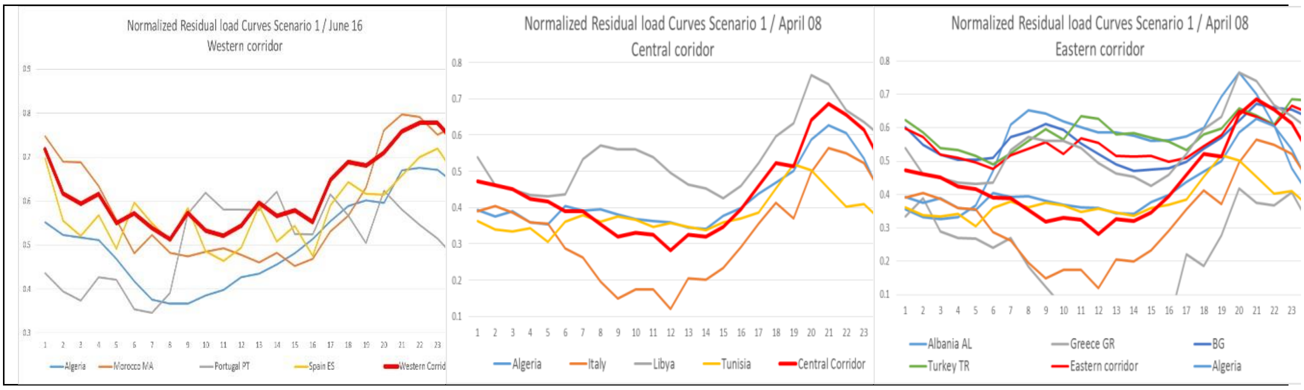


Figure. 5. Normalized individual and global residual load curves for a typical day in Scenario 1.

The figures 4 and 5 show that countries have very contrasted residual load curves according to their renewable share in the energy mix. For some countries, and depending on metrological conditions (wind and sun), residual demand can reach very low levels and its variation from one hour to another can be quite high.

These results are scenario dependent since renewable share in the energy mix vary from one scenario to another. For illustrative purpose, the next figure shows for the western corridor, June 20th 2030 residual demand for Scenario 4.

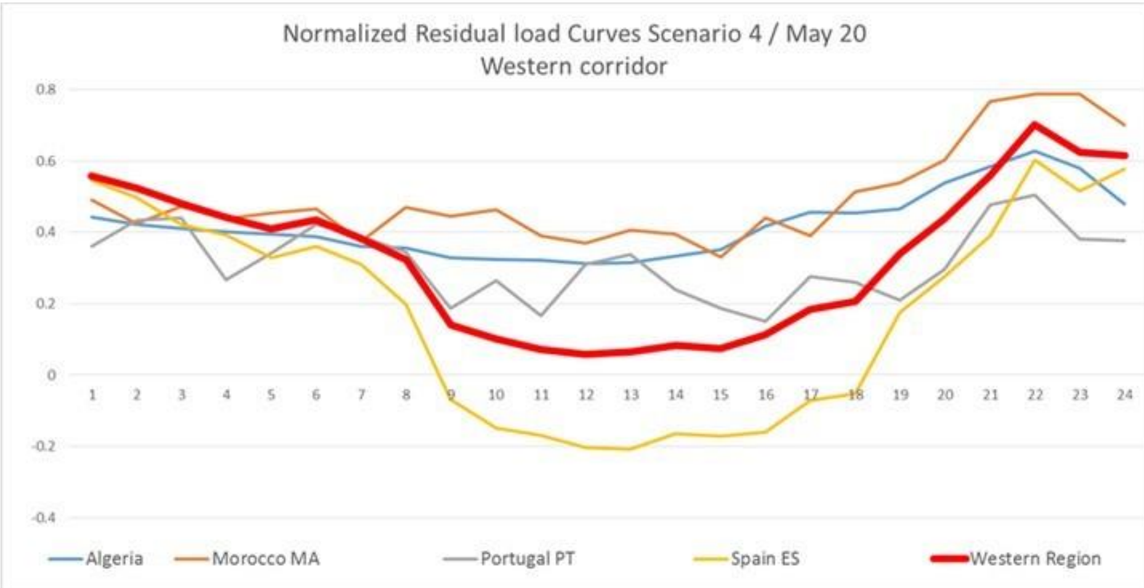


Figure 6. Residual demand curve for Western Corridor in Scenario 4.

As finding, and due to RES intermittence, residual load is even more variable then load itself, but when considering bigger areas (corridor or whole Med-TSO zone), the mitigation of both load and renewable generation results in a smoother and flatter global residual load curve. The effect is more important in scenarios where renewable share is higher.

Even if demand is a variable in the scenarios, the following is to give orders of magnitude in terms of forecast and rates of changes of growth. Basically, four groups of electrical systems are identified, splitting the Mediterranean power system by North and South, West and East.

DEMAND					
	TWh 2016	TWh 2030 S1	TWh 2030 S4	i% S1	i% S4
France	483	446	496	-8%	3%
Italy	314	354	355	13%	13%
Portugal	49	56	59	14%	20%
Spain	250	316	381	26%	53%
SubTotal North West	1096	1172	1291	7%	18%
Albania	6,6	12	12	75%	80%
Cyprus	4,9	6,1	7,0	25%	44%
Greece	51	60	60	18%	18%
Montenegro	3,2	4,6	4,7	45%	47%
Slovenia	14	16	16	15%	16%
Turkey	279	403	509	44%	82%
SubTotal North East	359	501	609	40%	70%
Algeria	64	130	160	103%	150%
Libya	36	103	106	184%	191%
Morocco	35	78	78	121%	121%
Tunisia	18	28	34	54%	87%
SubTotal South West	154	339	378	120%	145%
Egypt	163	363	371	123%	128%
Israel	n.a.	78	78	n.a.	n.a.
Jordan	19	41	43	122%	133%
Lebanon	n.a.	18	18	n.a.	n.a.
Palestine	n.a.	1	1	n.a.	n.a.
Syria	14	117	117	736%	736%
SubTotal South East	196*	618	629	166%*	172%*
Total	1805	2631	2907	46%	61%

*only for Egypt, Jordan, Syria

Table 2. Demand in the four sub-regions.

Table 2 is to give an idea (references Scenarios 1 and 4) that the demand in the Southern shore will grow more rapidly than the demand in the Northern one, more than doubling the current values from now to 2030, while the west northern shore demand will increase of about 7 to 18 % points in average. The northeast region will grow at an intermediate rate, between 40 and 70%.

2.3 The Generation Capacity

Still with reference to doc [6] generation shows complementarities as well.

Based on the analysis in the previous part of the document, showing a high diversity of load profiles, renewable shares, and generation technologies within Med-TSO area, and using results from the market study, the aim of this analysis is to assess the benefit coming from the usage of existing interconnections.

The analysis is performed considering a zonal approach through splitting the Med-TSO area in three corridors (Western, Central and Eastern).The following table presents the generation capacities in 2030 for the two most contrasted scenarios, i.e. 1 & 4. The current situation considered is the 2016 year from which the evolution rates (i% S1 and i% S4) are assessed.

	GENERATION CAPACITY							
	Generation capacity 2016 (GW)	*from which Solar and Wind (GW)*	Generation capacity 2030 S1 (GW)	*from which Solar and Wind (GW)*	i% S1	Generation capacity 2030 S4 (GW)	*from which Solar and Wind (GW)*	i% S4
France	131	*19*	132	*34*	1%	155	*63*	18%
Italy	114	*29*	120	*38*	5%	142	*66*	25%
Portugal	20	*5*	20	*6*	3%	28	*12*	42%
Spain	100	*30*	127	*53*	27%	178	*95*	78%
SubTotal North West	364	*82*	398	*131*	9%	503	*235*	38%
Albania	1,9	*0*	3,9	*0,2*	106%	4,3	*0,6*	130%
Cyprus	1,7	*0,2*	2,3	*0,9*	34%	2,6	*1,4*	52%
Greece	16,1	*4,5*	24	*10*	49%	33	*21*	103%
Montenegro	0,9	*0*	1,8	*0,1*	102%	1,9	*0,2*	115%
Slovenia	3,8	*0,3*	4,2	*0,3*	11%	6,4	*1,4*	68%
Turkey	78	*7*	126	*28*	61%	153	*50*	95%
SubTotal North East	103	*12*	162	*40*	58%	201	*74*	95%
Algeria	17,5	*0,1*	49	*9*	182%	64	*16*	270%
Libya	8,8	*0,0*	24	*3,3*	167%	24	*3,3*	167%
Morocco	8,3	*1,1*	21	*8*	156%	23	*10*	181%
Tunisia	5,2	*0,2*	9	*1,6*	75%	13	*4,1*	149%
SubTotal South West	39,7	*1,4*	103	*21,8*	159%	124	*33,3*	213%
Egypt	39	*0,9*	87	*8*	123%	91	*12*	134%
Israel	n.a.	*n.a.*	18	*0,1*	n.a.	18	*0,1*	n.a.
Jordan	4,3	*0,4*	11	*2,4*	147%	12	*3,9*	184%
Lebanon	3,0	*0*	4	*0*	46%	4	*0*	46%
Palestine	n.a.	*n.a.*	0,1	*0*	n.a.	0,1	*0*	n.a.
Syria	9,7	*0*	26	*0,9*	172%	26	*0,9*	172%
SubTotal South East	56	*1*	147	*12*	129%*	153	*17*	140%*
Total	563	*97*	811	*204*	44%	981	*359*	74%

*only for Egypt, Jordan, Lebanon, Syria

Table 3. Generation in 2030 [MW].

During the reference period (2016-2030), the TSOs foresee an increase in the generation capacity in the Mediterranean Countries of approximately 250 to 400 GW (Table 3), of which 40 to 60% from renewable energy sources (RES), in order to meet the expected increase in electricity demand of about 800 to 1100 TWh.

In the north-west area, almost all the additional capacity comes from renewables, not depending on the scenario. In the south where the generation growth is between 130% and 210%, most is provided by thermal new capacities even if renewables development can reach more than half the total is some countries.

2.4 The electricity flows at a regional level

Based on the analysis of the national load curves and the generation fleets showing a high diversity of load profiles, renewable shares, and generation technologies within Med-TSO area, and using results from the market study, the aim of the electricity flows analysis at a regional level is to assess the benefit coming from the usage of existing and future interconnections.
The analysis is performed considering a zonal approach through splitting the Med-TSO area in three corridors.

2.4.1 Western Corridor

The annual profile of exchanges between Spain and Morocco (to be considered as representative of the regional exchanges between Iberia Peninsula and Maghreb) are mainly driven by the seasonal complementarity. The following graph shows the U-shaped annual curve of the average monthly exchanges for the scenarios 1 and 4. It is to be notice that exchanges are well balanced in the greenest scenario 4, flows going more from South to North in winter and in the opposite direction in summer.

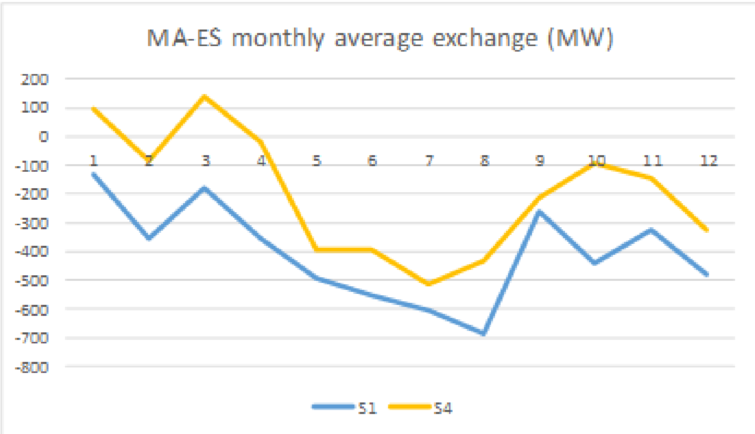


Figure 7. Spain-Morocco monthly exchanges.

A detailed analysis for this corridor can be done by focusing on one typical day of the Scenario 4.

At single country scale, episodes of high renewable generation could result in low residual load demand. To handle such situations, both thermal and pumping plants contribute to system adequacy. The following figure shows residual loads in Spain and in Algeria that are lower during the day due to PV generation. The most noticeable effect is a usage of hydro generation that lead to turbine in the night and pump within the day.

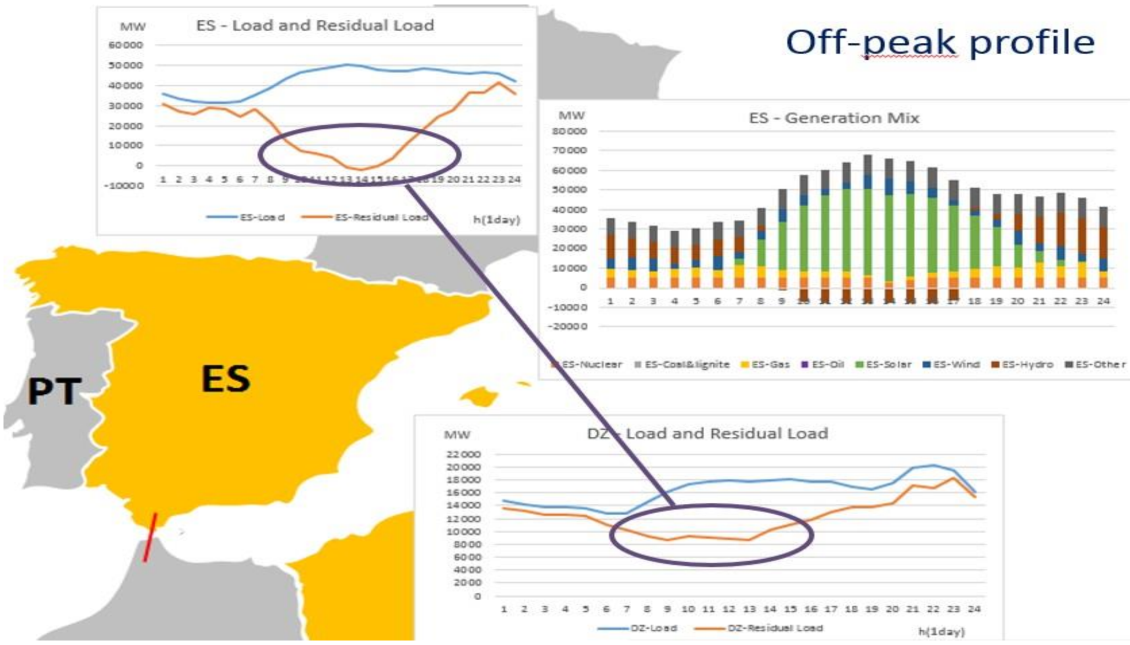


Figure 8. Focus on the Western Corridor.

On the other hand, episodes of renewables over generation can translate into exchanges opportunities with neighbouring countries. Even better, RES over generation can offer long distance exchanges opportunities. In the following graph, generation surplus in Spain when the peak of PV generation is mitigated by exporting at the maximum capacity simultaneously to France and to Morocco.

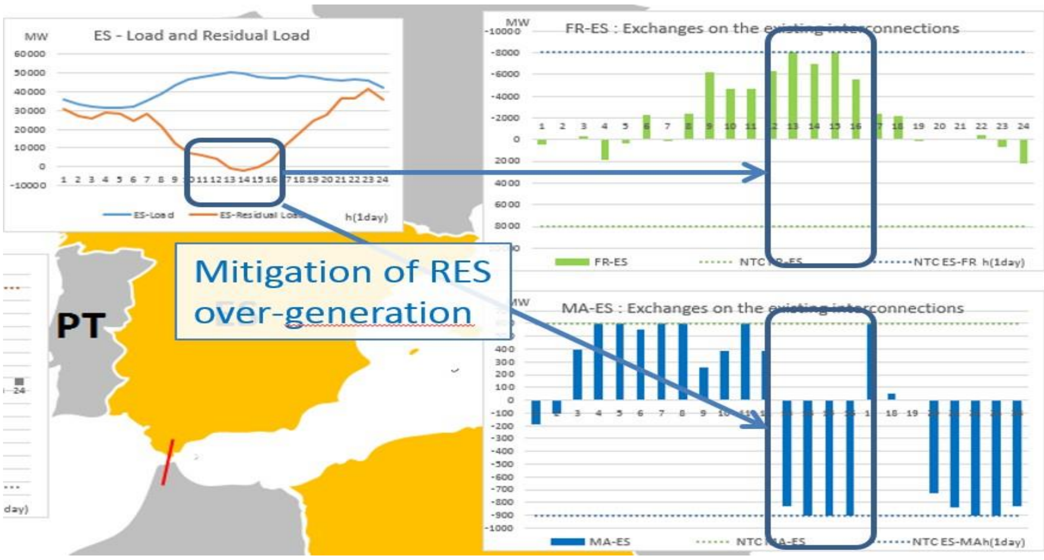


Figure 9. Mitigating generation surplus in Spain.

Additionally, it can be noticed a high volatility of exchanges and interconnections can be saturated in both directions in one single day.

2.4.2 Central Corridor

[6] focuses on one typical day of scenario # 1 in order to show the complementarity of generation that encourage the development of interconnections.

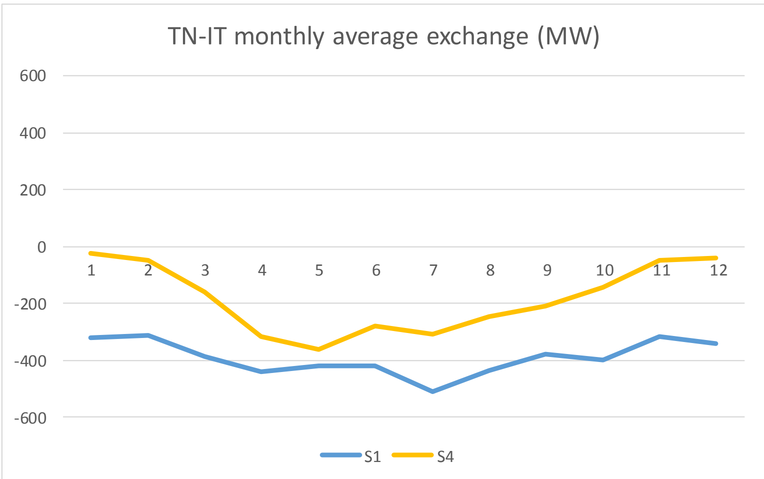


Figure 10. Spain-Morocco monthly exchanges.

Although in scenario 1, less renewables are developed in the southern bank of that corridor, interconnections are almost saturated from north to south especially in summer time. Energy flows coming from north bank through Italy-Tunisia interconnector to Tunisia but also to Algeria and Libya. This is due in part to high solar development in Italy and high demand in southern countries in summer season. Even for the other scenarios, flows still mainly from the north to south.

2.4.3 Eastern Corridor

For this corridor, the figures show that exchanges are well balanced with an energy flow in one direction during the night and an inverted energy flow during the day.

Turkey is exporting during the day due in part to its PV and is importing during the night from neighbour countries. In both directions, interconnectors are saturated.

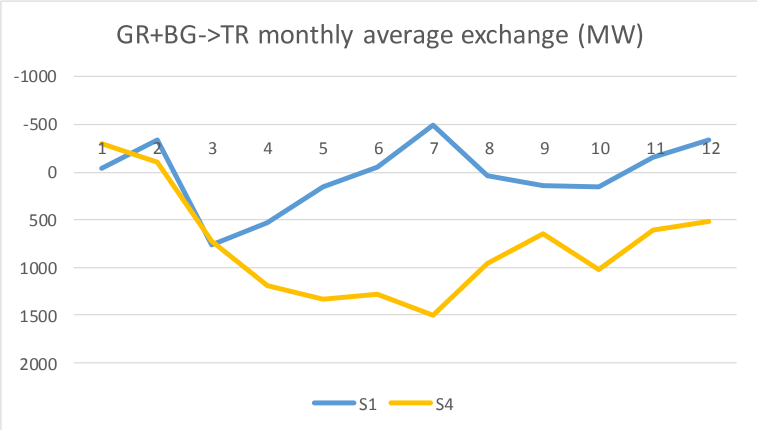


Figure 11. Bulgaria and Greece to Turkey monthly exchanges.

It can be notice that in the greenest scenario 4, flows in summer are almost saturated from Turkey to Bulgaria and Greece due to the PV generation in Turkey. Flows in the scenario 1 are more balanced, annual profile being mainly driven by the load in Turkey.

2.4.4 The status of the Interconnections in the Med-TSO Area

This is the status of current interconnections except of MMP document in Cpt 2.

1 Interconnection Morocco-Spain

The first interconnection was deployed in August 1997, when the 700 MW, 400 kV Morocco-Spain submarine AC link was completed from Tarifa (Spain) and Ferdioua (Morocco). With this realization, the integrated grids of Morocco, Algeria and Tunisia in the Maghreb region were put into synchronous operation with the UCTE system.

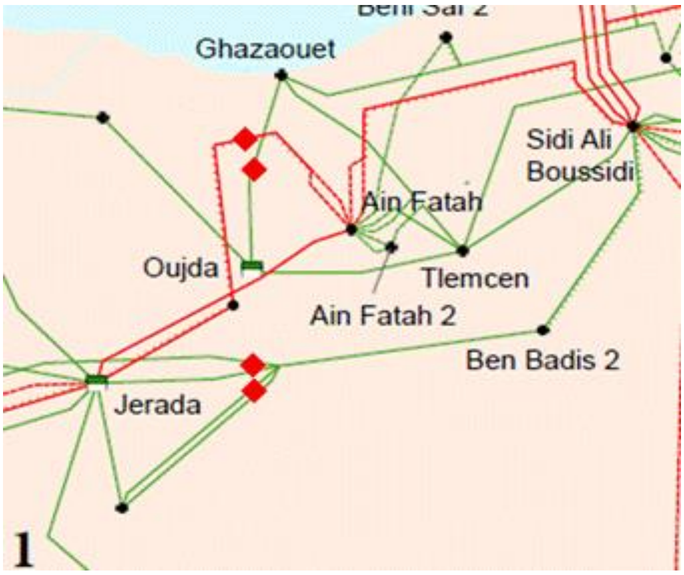
In July 2006, a second submarine AC link was put into operation between Spain and Morocco, increasing the TTC to 1400 MW and maximum net transfer capacity to 700 MVA. The link consists now of two 400 kV AC circuits of connections (700 MW each) with a total length of 31 km each, of which 28.5 submarine cable.

It is now the unique interconnection between North and South of Mediterranean Countries.

2 Interconnection Morocco - Algeria

At present Morocco and Algeria are linked through three AC lines (four circuits) for a total carrying capacity of 2500 MW and a NTC of about 1000 MW, namely:

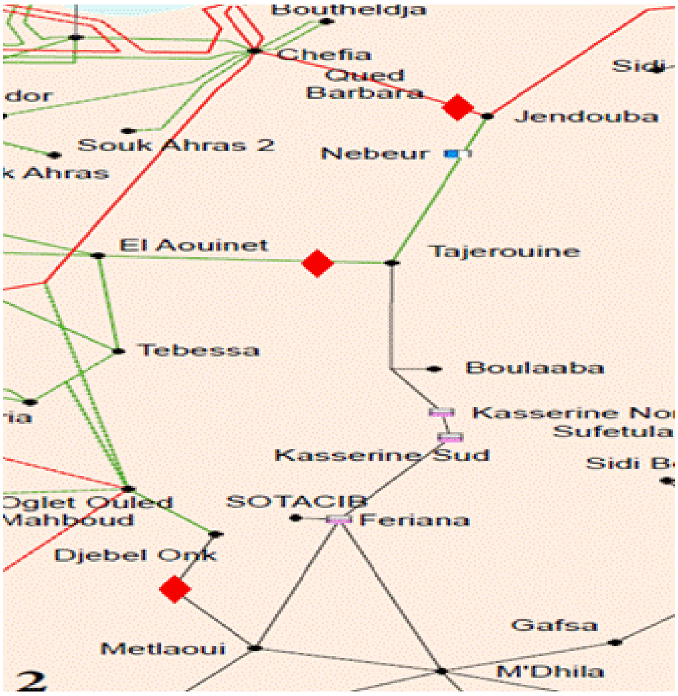
Oujda-Ghazaouet (225 kV, 46 km, 240 MVA) operating since 1988; Oujda-Tlemcen (225 kV, 64km, 240 MVA) in operation since 1991; Bourdim–Sidi Ali Boussidi (double circuits, 400 kV, 165 km, 2X1,100MVA) operating since 2009 and 2010.



3 Interconnection Algeria - Tunisia:

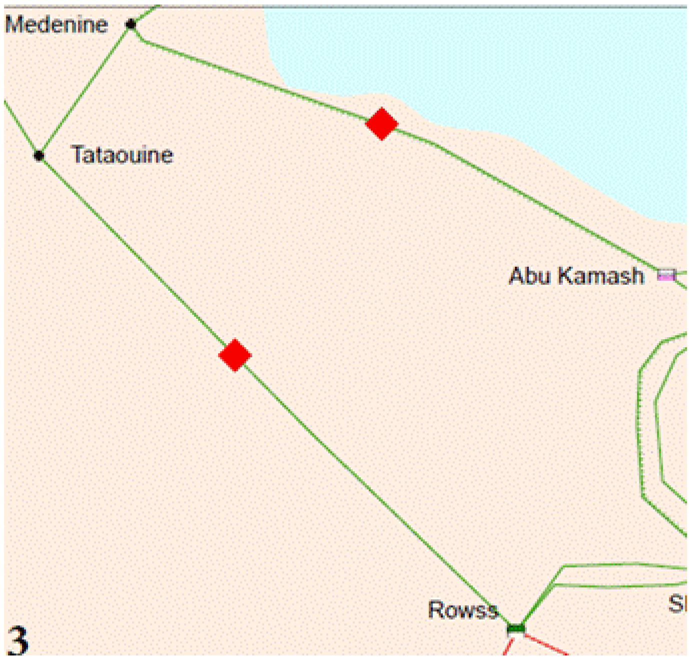
At present Algeria and Tunisia are linked through four AC lines: El Aouinet - Tajerouine (225 kV, 59 km, 250 MVA, in operation since 1980); Djebel Onk – Metlaoui (150 kV, 62 km, 160 MVA, 1984); El Aouinet –Tajerouine (90 kV, 60 km, 60MVA, 1953); El kala –Fernana (90 kV, 93 km, 80 MVA, 1956).

A fifth line at 400 KV (160 km, 1,067 MVA) from Chefia (A) to Jendouba (T) has been commissioned back to 2013 , thus reaching a TTC of 1,500 MW and a NTC of about 300 MW (out of service of the 400 kV line and decommissioning of the 90kV and 150 kV lines).



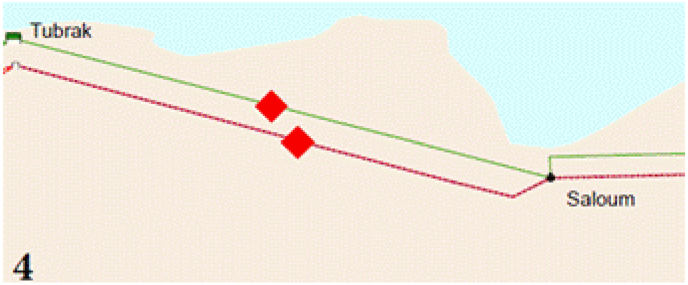
4 Interconnection Tunisia- Libya

The two existing AC lines (3 circuits) Mednine – Aboukamash (225 kV double circuit, 2x250 MVA) and Tataouine – El Roweis (225 kV, 250 MVA), are normally not operated due to stability problems in case of connection of Tunisia to the Libya-Egypt synchronous system.



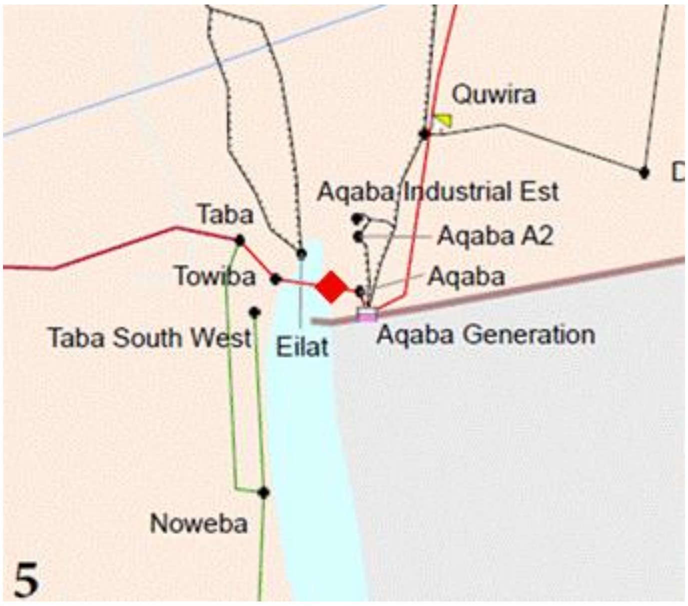
5 Interconnection Egypt- Libya

Libya and Egypt are connected by a 220 kV double circuit line operational since 1998, between Saloum and Tobruk. A project exists to upgrade it to 400/500 kV (see 5.3.2), thus strengthening the connection between Maghreb and Mashreq through Libya.



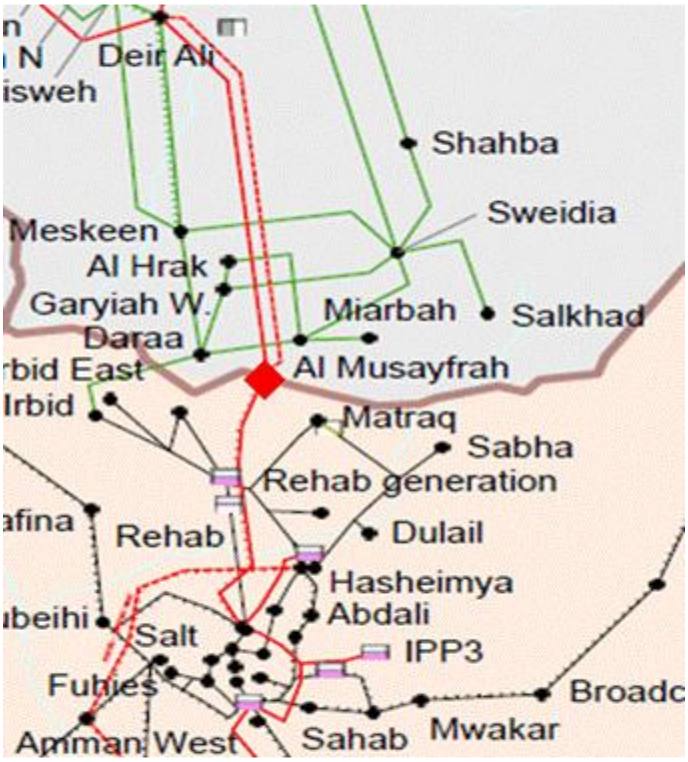
6 Interconnection Egypt - Jordan

Since 1998, Egypt operates a 400 kV AC submarine cable (13 km) crossing the Aqaba Gulf to Jordan (Taba 500/400 kV substation in Egypt with Aqaba 400/132 kV substation in Jordan) with a commercial transfer capacity in the order of 500 MW from Jordan to Egypt and of 500 MW from Egypt to Jordan (thermal capacity 550 MW). This interconnection is at the moment mainly used for electricity exports from Egypt to Jordan, and further to Syria and Lebanon. An agreement was reached between the interconnected countries that Egypt will export - when available - 450MW to be equally shared between the three Countries (Jordan, Syria and Lebanon).



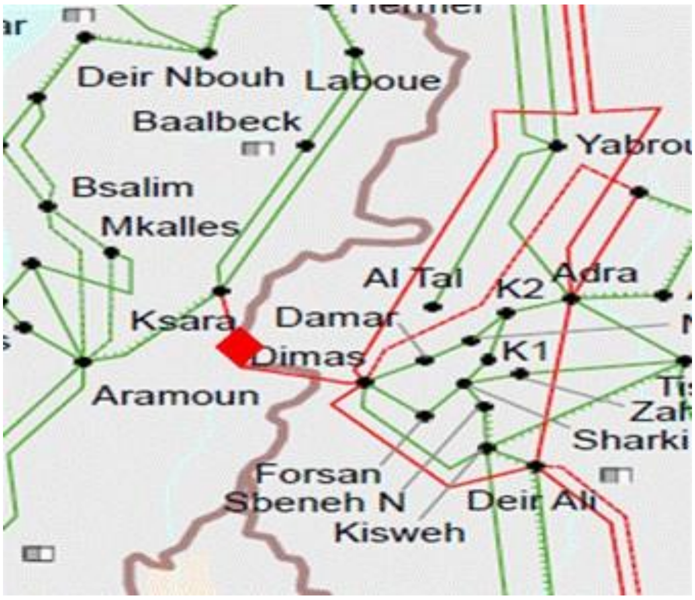
In the future (around 2022) it is intended to transform the Taba - Aqaba connection, now operated in AC to be DC in order to raise its capacity up to 1200 MVA. In addition, Jordan is expected to strengthen the internal network through a 400 kV double circuit between Aqaba (South of Jordan) and Amman (North of Jordan). With these reinforcements there will be two corridors (four 400 kV circuits) between North and South of Jordan.

7 Interconnection Jordan Syria



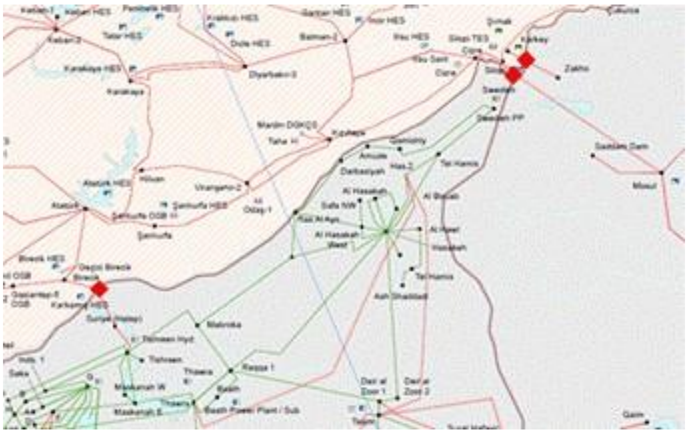
One 400 kV single circuit transmission line 154 km connects Der Ali 400/230 kV substation in Syria with Amman north 400/132 kV substation in Jordan. Line Transportation Capacity 500 MVA (thermal about 1,100MVA). A possible future second 400 kV line has not yet been confirmed.

8 Interconnection Syria Lebanon



Lebanon receives electricity from Syria through a 400 kV line, a 220 kV line and one 66 kV line double circuit. The maximum transfer capacity from Syria to Lebanon is about 850 MW. This capacity is limited now at 300 MW by the transformer capacity of the 400 kV substation of Ksara (Lebanon); the import capacity will be increased with the reinforcement of the substation (additional 300 MW).

9 Interconnection Turkey Syria and Turkey Iraq



Syria and Jordan were connected in 2001 by means of a 400 kV AC overhead line with a commercial transfer capacity of 450 MW (thermal line capacity 800 MW). The Turkish system is no longer connected with the Syrian one and electricity is only exchanged sporadically, when Turkey feeds power with maximum 380 MW to so-called "electricity islands" - areas in Northern Syria being temporarily isolated from the Syrian main grid.

The electricity transmission corridor along the East Path remains incomplete as long as the Syrian and the Turkish electricity systems are not connected. There is a plan for a DC back-to-back interconnection with 600 MW capacity, and tendering process for the Installation of DC back-to-back station in the Turkish territories on the existing 400 kV line is ongoing.

Syria is a net electricity importer, receiving power through commercial exchanges from Jordan and Egypt, but it also exports (to a lesser extent) electricity to Lebanon.

10 Connections of Turkey with Georgia, Iran

These connections of Turkey with Countries not members of Med-TSO do not correspond to a synchronous operation of the power systems. They are connections of the Turkish power system to isolated areas of the other systems.

11 Interconnections Turkey Greece and Bulgaria

On 18 September 2010, the Turkish power system was synchronized to the Continental Europe Synchronous Area (CESA). After a trial period, TEIAS became Observer in ENTSO-E. The parallel operation is achieved by two 400kV lines to the Bulgarian system and by one 400 kV line to the Greek system:

Hamitabat (Turkey) - Maritsa East (Bulgaria), 400 kV- 133 km (995 MVA)

Hamitabat (Turkey) - Maritsa-East (Bulgaria), 400 kV- 145 km (1,510 MVA)

Babaeski (Turkey) - Nea Santa (Greece), 400 kV – 130 km (1,510 MVA)

At the moment some limiting factors, not related to the grid expansion, are still present but on the way of being solved. As a result of that, total NTC values are limited to 650 MW on CESA to Turkey direction and 500 MW on the opposite direction. Two thirds of this NTC are presently allocated to the Bulgaria to Turkey connection and one third is allocated to the Turkey to Greece connection.

The second Greece to Bulgaria and the related strengthening of the 400 KV south East Bulgaria network which is under way, will contribute to the increase of future NTC to 1350 MW on CESA to Turkey direction and to 1250 MW on the opposite direction.

12 Interconnection Portugal-Spain

The Portuguese transmission network has at present nine interconnection circuits with the Spanish transmission network, namely:

six at 400kV:

Alto Lindoso (PT) - Cartelle (ES) 1 and 2 (1386MVA each);

Falagueira – Cedillo (1386MVA);

Lagoaça - Aldeadávila (1386MVA);

Alqueva - Brovales (1640MVA);

Tavira – P.Guzman (1386MVA).

three circuits at 220kV:

Pocinho-Aldeadavila 1 and 2 (435MVA each);

Pocinho-Saucelle (430MVA)

In permitting phase:

New double OHL Ponte de Lima (PT) – Fontefría (ES) 400kV (initially only one circuit installed);

The above-mentioned lines along with this one new 400kV line will allow the interconnection capacity reinforcement between Portugal and Spain in the medium term in order to reach by 2021/2022 a 3500/4200 NTC.

13 Interconnection France – Spain

The current exchange capacity is around 2.5 to 3 GW in the both directions, following the construction of an HVDC underground link (2 GW between Sta Llogaia in Spain and Baixas in France, East of Pyrenees mountains) and a phase shifting transformer installed at Arkale station.

The Biscay Gulf project planned for 2030 envisages 370 km HVDC-VSC link (2 bipoles of 1000 MW each) mainly subsea in the Biscay Gulf, between Gatica (ES) and Cubnezais (FR). Expected NTC is 5 GW MW in both directions.

Further, a New Central Pyrenees (2x1000 MW HVDC and West Pyrenees (2x1000 MW) interconnections is under consideration. Internal 400KV reinforcements are needed in Spain and in France. Expected NTC is 8 GW in both directions.

14 Interconnection France-Italy

The existing lines between France and Italy through the Alps provide 3200 MW exchange capacity from France to Italy and 1200 MW in the opposite direction.

A new underground HVDC link 285 km long (+1,200 MW) is under construction between Grand-Ile (F) and Piossasco (I) for an expected benefit of 1200 MW from France to Italy direction and 1000 MW in the opposite direction..

3 Market Studies

3.1 Introduction

One of the main purposes of the market model is to assess the benefits of investments clusters (aimed to increase the exchange capacity among Med-TSO countries), with particular reference to:

- Security of supply;
- Social Economic Welfare;
- RES integration;
- CO2 emission.

The evaluation of scenarios is the modern approach to System planning. It is the starting point to orient the development of the grid in a market environment. The Med-TSO methodology includes this activity in the planning process. The overall process from scenario definition to final project evaluation includes the following five steps:

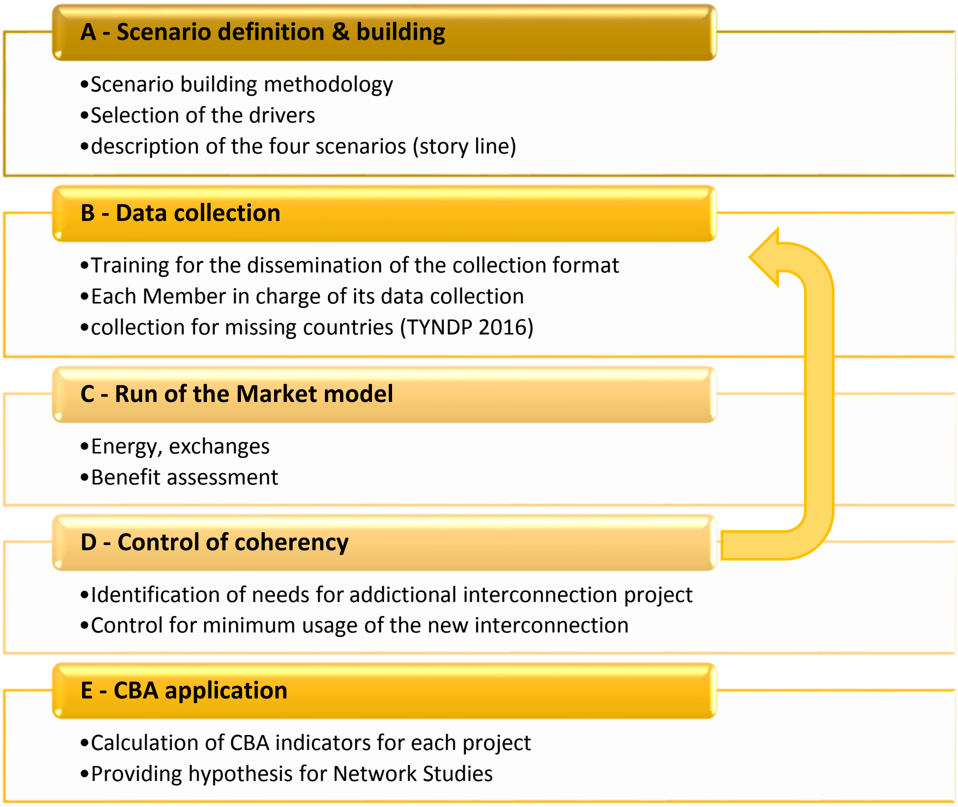


Figure 7. General Process of Market Studies.

This work was started since the winter of 2015-2016 by the members of Med-TSO, with a special effort on training on the Market Model.

Collaboration with ENTSO-E was important during the data collection phase, and more generally to ensure methodological consistency between the TYNDP and the Mediterranean Master Plan.

3.2 The methodology

A - **Scenario definition & building**

The construction of multiple generation-demand scenarios for evaluating new transmission assets is an essential tool for dealing with uncertainties. The scenarios lay down technical and economic assumptions and identify possible solutions.

Scenarios analysis intends to deliver a set of multiple diversified and plausible future environments and TSO strategies for power systems. Scenario analysis gives decision makers an overview of future perspectives and facilitates decision making in complex and unpredictable situations.

The aim of those Med-TSO 2030 scenarios is to build the path from now to several possible futures (trends on load and generation) to give a robust framework for grid development studies. The Euro-Mediterranean region is characterized by wide contrasts and complementarity in terms of load growth and of renewable energy development. It results a high level of uncertainty regarding the long-term load forecast in the countries where growth rate remains significantly positive. Moreover, many areas show a very good potential in terms of wind or irradiation that could offer opportunity of a massive RES development.

In this context of high uncertainty, a set of four long-term Med-TSO 2030 Scenarios has been built.

B - **Data collection and Reference Grid**

The model of each Mediterranean country is provided by each Med-TSO member, except for few countries (Israel, Egypt, Palestine, Syria and Lebanon) that are modelled starting from available data to obtain an average scenario.

The model is an equivalent busbar without the detail of the transmission grid, including load and generation (thermal power plants) that cannot be dispatched. Not dispatchable[13] generation such as other non-RES and RES generators, run of river units and hydro pumping power plants, wind farms and photovoltaic power plants) are specified.

The analysis of the impact of each investment could be made considering alternatively the following methodologies. For certain clusters both methodologies may be considered:

- The TOOT (Take Out Once at Time) methodology consisting of excluding investment items (line, substation, PST or other transmission network device) or complete projects from the forecasted network structure on a one-by-one basis and to evaluate the load flows over the lines with and without the examined network reinforcement (a new line, a new substation, a new PST, etc.).
- The PINT (put in once at the time) methodology considers each new network investment/project (line, substation, PST or other transmission network device) on the given network structure one-by-one and evaluates the load flows over the lines with and without the examined network reinforcement.

For the Reference Grid definition, every country has a defined Bilateral Transfer Capacities (BTC) with interconnected neighbouring countries that helps to guarantee the security of the electricity supply power system and allows economic exchanges of electricity. Med-TSO BTCs for year 2030 have been addressed by Med-TSO members, while for ENTSO-E countries included in TYNDP 2016 [39] public data have been used.

[13] Not dispatchable are the generation which cannot be scheduled (e.g. wind generation) or have the priority of dispatching (e.g. auto production systems)

BTC TO FROM	AL	AT	BE	BG	CH	CY	DE	DZ	ES	EY	FR	GB	GR	IE	Is	ITn	ITs	JO	Le	LU	LY	MA	ME	MK	Pa	PT	SI	SY	TN	TR
AL													250										350	200						
AT					2500		7500									1655											1200			
BE							1000				2800	1000																		
BG													1732											300						1340
CH		2200					5000				1300					6240														
CY																														
DE		7500	1000		5000						4800																			
DZ																						1000							300	
ES											8000											900				4200				
EY																		550			550				150					
FR			4300		3700		4800		8000			5400		700		4350														
GB			1000								5400			500																
GR	250			1034													500							350						660
IE											700	500																		
Is																														
ITn		1385			3860						2160						4000										1380			
ITs													500			1750							1200						600	
JO										550																		800		
Le																												500		
LU																														
LY										550																			500	
MA								1000	600																					
ME	350																1200													
MK	200			150									400																	
Pa										150																				
PT									3500																					
SI		1200														1530														
SY																		800	500											600
TN								300									600				500									
TR				1340									580															600		

a) Between Med-TSO Members

BTC TO FROM	AT	BA	BE	BG	CH	CZ	DE	DK	EE	FI	GB	HR	HU	IE	LT	LU	LV	ME	MK	NI	NL	NO	PL	RO	RS	SE	SI	SK
AT					2500	1000	7500						1200														1200	
BA												1844						500							1100			
BE							1000				1000										2400							
BG																			300					200	400			
CH	2200						5000																					
CZ	1200						2600																800					2100
DE	7500		1000		5000	2000															5000	1400	2000			1200		
DK																												
EE										1000							1250											
FI									1000													100				3150		
GB			1000											500						450	1000	1400						
HR		1812											2000												600		2000	
HU	800											2000												1300	600		1700	2000
IE											500									1100								
LT																	1500						1000			700		
LU																												
LV									1200						1300													
ME		400																							1100			
MK				150																					640			
NI											80			1100														
NL			2400				5000				1000											700						
NO							1400			100	1400										700					3695		
PL						1800	3000								1000											600		990
RO				300									1400												1400			
RS		1200		300								600	700					1100	800					1300				
SE							1200			3150					700							3995	600					
SI	1200											2000	2000															
SK						1100							2000										990					

b) Between non MedTSO Members

Table 6: BTC in the Reference Grid.

C – **Run of the model**

The simulation tool implements a day-ahead energy market, characterized by a system marginal cost and by a congestion management based on a zonal market splitting. The study is accomplished through the application of a Monte Carlo simulation model on a Mediterranean/European wide basis. The Market Studies software tool carries out an optimal coordinated hydrothermal scheduling of the modelled electric system generation set, over a period of one year.

One purpose of the market model is to assess the benefits of investments clusters (aimed to increase the exchange capacity among Med-TSO countries), with particular reference to: **Security of supply.**

Social Economic Welfare; **RES integration**; **CO2 emission**.

D – **Consistency check**

The sequence of Data collection and Run of the model is performed in an incremental process.

The objective of the approach is to validate the assumptions of the Market Model on the basis of provisional results. A consistency check is carried out at the end of the first round, which has made it possible to update the consumption and production assumptions based on the most recent information, in particular to take into account the latest developments in national environment policies and development of renewable energies.

This consistency check is also intended to revise the list of exchange capacity building projects between countries. This control validated that all projects considered in the first round [9] were useful in terms of exchange. However, this control also showed that some interconnections had a high saturation rate even though no project had been initially selected. The list of Projects to assess has been improved in order to cover those interconnections by adding several project in the North African countries from Algeria to Egypt to reinforce significantly the existing coastal West-East backbone.

E – **CBA application**

For each cluster, Market Studies provide the variation of EENS (Expected Energy not Supplied), Social Economic Welfare (SEW), RES Curtailment and CO_2 emissions is shown. These values refer to the total electrical system. Then, economic benefits (EENS monetization and SEW) evaluated for additional exchange capacity provided by the new interconnection are presented; it is worth to mention that marginal benefits for each MW are calculated given the size of the cluster under analysis.

It is worthwhile to note that the major part of the monetized benefits is associated to SEW variation (that is equal to system generation costs variation) derived from the interconnection of areas with different marginal prices and the reduction of RES curtailment. Benefits related with EENS reduction are very limited because each country plans the expansion of its own electric system to avoid not admissible EENS level. This not means that the interconnection clusters have no effect on the adequacy of the interconnected system because it is obvious that increasing exchange capacity has an impact on the ability of the electric system to assure the coverage of the load. In general, the presence of investment to strengthen the network can influence generation investments and the possible saving can increase the benefits of a cluster.

3.3 The input data

As described in [1] and [5] Med-TSO scenarios for 2030 are defined with reference to six sets of drivers:

- **Economy and population** (GDP growth, population growth, demand forecast, primary resources price);
- **Renewable energy development**;
- **Technology development** (storage, load management, smart grid);
- **New load** (water de-salinization, electric cars, public transportation, energy efficiency);
- **Market integration** (internal market, regional market, or global market);
- **Thermal carbon free technologies** (i.e. nuclear development in the South of the Mediterranean area).

In particular, four scenarios have been developed:

- Scenario 1 – **Business as usual** and security of supply improvement
- Scenario 2 – **Green Future** based on gas and on local integration of renewable energies
- Scenario 3 – High economic growth which supports high **Interconnection development** and free carbon thermal plants development in the South of the Mediterranean area
- Scenario 4 – **Green future and market integration** at an international level

The Table below summarizes the level of the 6 drivers for each scenario, the minimum value being 1 and the maximum value 3.

Drivers/Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Economy and Population	2	2	3	2
Renewable energy development	2	2	2	3
Technology development	2	3	2.5	3
New Load	1	3	2	3
Market Integration	1	1	3	3
Thermal carbon free technologies	1	1	3	3

Table 7. Scenario drivers.

It is important to note that, for all scenarios, the "RES development" driver is always at least equal 2. Indeed, all the questioned experts consider for their country a “Medium to Strong” evolution of the RES development, and generally in acceleration by comparison with the past trend.

For the Euro-Mediterranean Power system, there is therefore a key issue to retain assumptions for all countries in the perimeter of ENTSO-E for each of the four scenarios. This consistency is facilitated because the scenario building methodology used by Med-TSO is similar to what adopted in ENTSO-E, in particular, four visions are introduced to be used for Ten-Year Network Development Plan (TYNDP 2016) calculation.

To have a coherent approach between the two TSO associations, the economic model for each Med-TSO scenario are coherent with ENTSO-E Visions for European countries when the adopted matching is as following:

- Med TSO Scenario 1 ↔ENTSO-E Vision 1
- Med TSO Scenario 2 ↔ENTSO-E Vision 2
- Med TSO Scenario 3 ↔ENTSO-E Vision 3
- Med TSO Scenario 4 ↔ENTSO-E Vision 4

However, the detailed comparison of scenarios 2 and 3 of Med-TSO and ENTSO-E reveals a divergence on the use of coal and gas power plants. In fact, Med-TSO has preferred in scenario 2 a control of CO_2 emissions which is based in part on the use of natural gas to the detriment of coal (gas power plants are built in the South for the adequacy of supply and to minimize CO_2 emissions).

For that, Energy and CO_2 price need to be set up to have a Merit Order with gas before coal, that implies a switch of Visions 2 and 3 fuel and CO_2 prices compare to ENTSO-E TYNDP 2016 assumptions.

Regarding the **load forecast for 2030**, consumption in the perimeter of Med-TSO is in the range of **2450 TWh to 2770 TWh**, when 2015 value is 1825 TWh. Globally the scenarios 3 and 4 consider a higher development of electricity sector because of new electricity uses like public transportation. Average growth rate against 2015 value are between 2% and 3%.

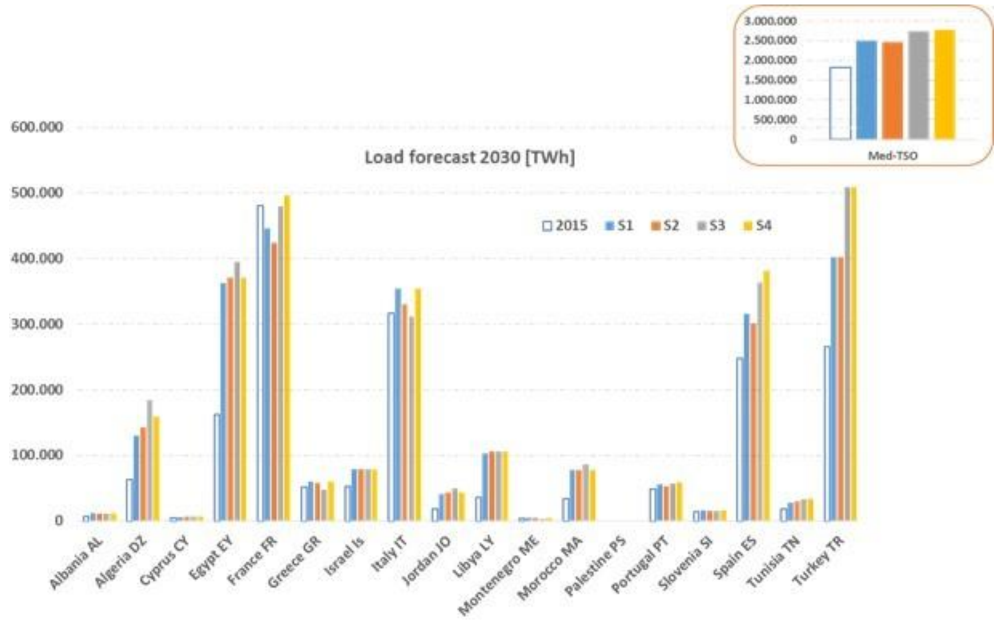


Figure 8. Load forecast in Med-TSO 2030 Scenarios.

On Generation side, the focus on RES development shows an impressive growth in both solar and wing Generation. In term of generated energy, Solar increases between 3 and 7 times and Wind between 2 and 4 times.

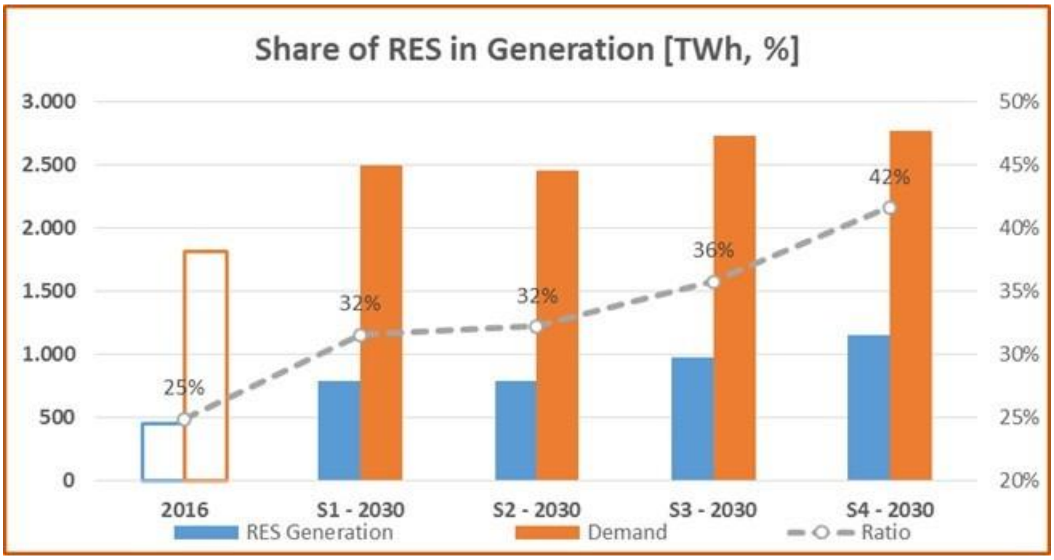


Figure 9. Share of RES Generation in Med-TSO 2030 Scenarios.

More generally, the share on RES in the Power system mix is between 32% in the scenario 1&2 to 42% in the Scenario 4.

3.4 The Projects

For Projects definition, Mediterranean area has been split in three parts:

- Western side (Algeria, France, Morocco, Portugal, Spain);
- Central side (Algeria, Egypt, Italy, Libya, Montenegro, Slovenia and Tunisia);

- Eastern side (Albania, Cyprus, Egypt, Greece, Israel, Jordan, Lebanon, Palestine, Syria, Turkey and Bulgaria[14]).

The following investment clusters have been considered.

In the Western Corridor, three projects have been studied, connecting Iberian Peninsula and Maghreb:

Countries	Capacity (MW)	Maturity	Comment
Morocco - Portugal	1000	Under discussion	
Morocco - Spain	1000	Under discussion	
Algeria - Spain	1000	Under discussion	

Table 8. Selected Studied Projects in the Western Corridor.

In the Central Corridor, some of the Projects are connecting south Italy and Maghreb while others are intended to reinforce the South Bank backbone from Algeria to Egypt.

Countries	Capacity (MW)	Maturity	Comment
Algeria - Italy	1000	Under consideration	
Tunisia – Italy I	600	Project included in the PCI list and commissioning is expected by 2025 (feasibility study stage)	Project included in the Reference scenario
Tunisia – Italy II	1200	Under consideration	
Tunisia Algeria-	700		Added due to the long saturation hours in the existing ones
Tunisia – Libya – Egypt	1000	Under consideration	Was considered in ELTAM study

Table 9. Selected Studied Projects in the Central Corridor.

In the Eastern Corridor, some projects are on-land while others consider submarine solutions.

Countries	Capacity (MW)	Maturity	Comment
Greece – Turkey - Bulgaria	500 + 500	Under consideration	Main driver of the project to increase the transfer capacity in the CESA to Turkey transmission corridor
Turkey – Syria – Jordan	600 + 800		Main driver of the project to double the transfer capacity in the Turkey – Syria – Jordan transmission corridor
Jordan - Egypt	550		Main driver of the project to double the transfer capacity between Egypt-Jordan
Greece – Cyprus – Israel	2000 + 2000	Planned (PCI TYNDP ENTSO-E)	Main driver of the project to create the electricity highway Israel-Cyprus-Greece and to end the Energy Isolation of Cyprus.
Turkey - Israel	2000		Main driver of the project to develop a new corridor in the eastern Mediterranean
Turkey - Egypt	3000		Main driver of the project to develop a new corridor in the eastern Mediterranean

[14] Bulgaria is not a Med-TSO member, but the Bulgarian full Bulgarian model was kindly provided by ESO to be included in the analysis of the cluster GRTRBG.

Table 10. Selected Studied Projects in the Eastern Corridor.

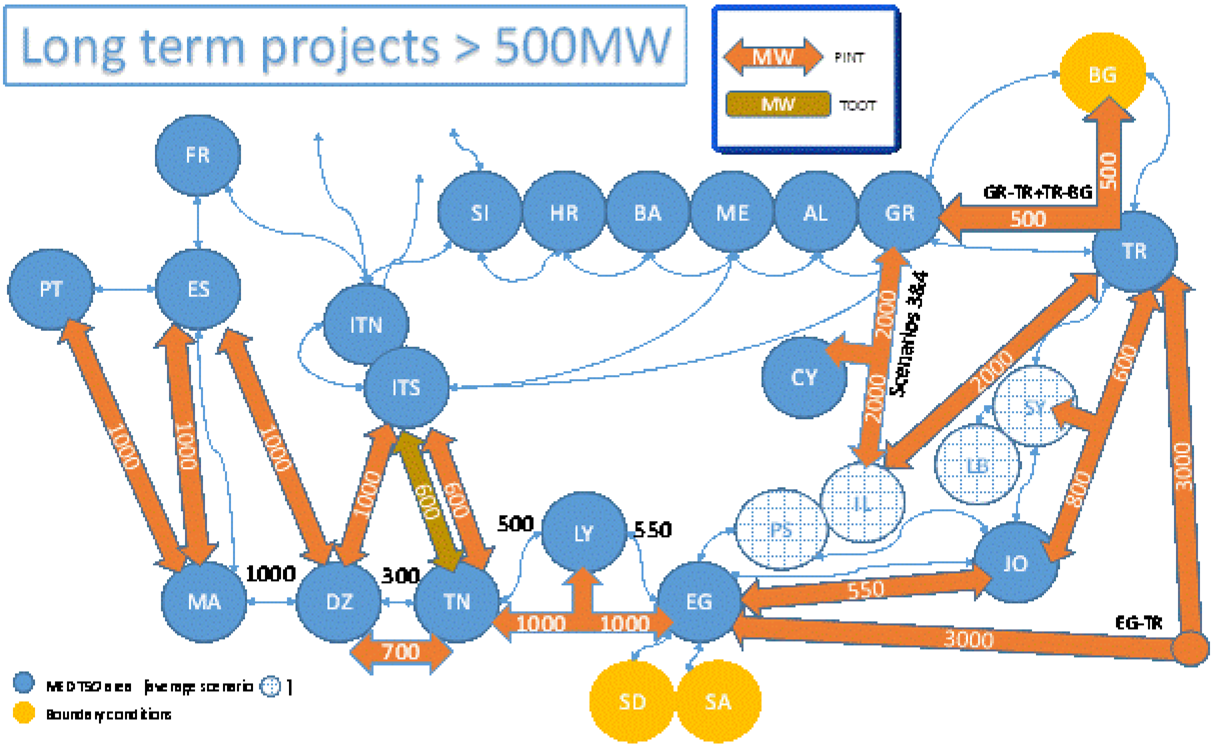


Figure 10. Map of the Projects to be assessed.

4 Network Studies

4.1 Introduction

Network studies [1], [3] are performed in order to assess the feasibility of the projects proposed as outcome on the Market studies. More precisely the network studies simulate the project in the networks to verify the security of operation against given contingency lists and to design remedial reinforcements to bring back the system in security standard conditions. The same project is feasible if it is feasible from the physical point of view and the CBA is convincing for the investors.

The market studies analysed the effects on the market of 14 interconnection projects (clusters). The network studies delivered the same projects and all the internal electricity grid reinforcement needed to guarantee the reliability of the interconnections and consequently the security of electricity supply in the Mediterranean Region. In order to evaluate the reinforcements an adequate network model for network analysis is needed. This model merged with the load and generation injections allows running security analysis. Certain internal reinforcements are proposed in the systems involved with the aim to alleviate the violations identified by the security analysis.

While is some cases it is sufficient to evaluate some benefits (KPIs) without a thorough simulation of the behaviour of the grid within the market studies (e.g. welfare, ENS, etc.) the network studies are needed to investigate the feasibility and to assess overall costs of the projects to be included in the Cost Benefit Analysis [7], [8]. The differential active losses with and without the project, which are as well calculated with the network studies, are also part of the overall costs.

The network studies do not include a detailed design of the facilities, as this is not in the main scope of the network studies within the framework of the Mediterranean Master Plan. Nevertheless, adequate representation (full system or equivalent) is adopted for the systems involved.

[1] outlines the general methodology adopted in Med-TSO and in the MMP 2018.

This Chapter tries to summarize the results (assessment of the 14 projects) at the end of the process and highlight some relevant aspects.

4.2 Methodology

4.2.1 Bridging Market and Network (alias Point in Time / Snapshot Selection)

Within the market studies there are 14 clusters identified and selected [11] for future possible development in the Mediterranean region. As mentioned above, initially the TSOs proposed only 10 projects to be considered in the market studies. However, following the first round of the market studies (round A), the results of the calculations indicated that there was room for increasing the cross-border exchange capabilities , namely in the countries of the south shore of the Mediterranean. According to these findings, four additional projects have been included. Therefore, all the 14 interconnection projects have an added value in terms of interconnection capacity within the Mediterranean Region and improve the adopted KPIs [7], [8].

Then, after the market studies have provided the results, the 2nd step to the process can be done, i.e., the selection of the hours from the 8760 hours simulated in the market studies, that can be simulated in the network studies.

Therefore, based on the information from the market studies, it is crucial to build up a significant number of grid snapshots (i.e. a punctual picture of the network merged with the loads and generations which are representative of most probable future operating conditions). In other words, it is necessary to detect grid hours significant per stress of the system and per occurrence significant to assess the grid reinforcements.

Consequently, the hourly simulations available from the market studies are the basis for the Point in Time (PIT) selection. This step is called “Point in Time Selection” described in more detail in [11] and the main goal is to find the limited number of hours from the Market studies that can be simulated in the load flow analysis, considering the criteria more suitable for the countries involved in terms of the detection of the grid reinforcements as well as the losses impact evaluation.

As far as this step is concerned, two PITs per scenario were considered in general sufficient to define the physical environment where the project will be in operation. However, because of the main goal of the PiT selection is related with the grid reinforcements assessment, different number of PiTs per scenario can be considered in some clusters. Nevertheless, the total number of the PiTs selected (for the 4 scenarios considered in the market studies) not exceeded 9 per cluster.

Therefore, for each PIT selected, the merged network was built (a snapshot) considering he number of countries that are relevant for each specific interconnection project, as well as considering a boundary conditions for the other neighbour interconnected countries. These snapshots were used for network calculations for each of the 14 interconnections under assessment. As mentioned before, each interconnection project required different extensions of the networks to be modelled. In some cases, neighbouring systems were merged with one or two levels; in some other cases, it was sufficient to simplify the model of some connected neighbours (representation as boundary conditions). Finally, in few cases a simplified model was adopted (equivalent network) in lack of data[15]. The compatibility of reinforcements with the National Development plans remain sole individual responsibility of TSOs, because this MMP only focus in the 14 interconnection projects assessment and their impact in the grids. The TSOs are also asked to verify autonomously the planned network with these new interconnections and their grid reinforcements in terms of transient stability conditions.

In general, the simulations have been performed in DC approximation because of the size of the merge grids and because considered enough for scope of the network studies. AC simulation has also been applied in the particular cases of some interconnection projects, that that voltage issues have been identified. This approach has been suggested to allow implementing a high number of simulations, even though simplified (DC), instead of a limited number of detailed ones (AC).

The load flow simulations were performed to assess the security of operation, basically in N, N-1 and/or N-2 contingency analysis (N-2 according to a specific list in some countries) taking into account the limits of voltage and thermal capacity of grid elements adopted by each TSO as agreed in [1,2].

At the end of this process, the network study was done, and the list of internal grid reinforcements is identified and agreed for each interconnection project and the losses estimation with and without the interconnection project and relevant reinforcements are calculated.

4.2.2 The Costs of the assets (investment costs)

After the internal network reinforcements assessed and defined, as well as the main figures of the interconnection projects defined, the monetization of these infrastructures were considered in order to include in the CBA. Therefore, in the Cost-benefit analysis the costs of the assets include costs of the interconnection project plus the costs of the internal reinforcements relevant for each specific project. In Med-TSO, it has been agreed to evaluate costs of the internal reinforcement at the standard costs proposed by each TSO of the country concerned and the costs of the interconnection project at standard costs of the technology used for each project. The TSOs, together with a third party proposed the most probable technologies to be implemented for each interconnection project and related costs.

4.2.3 Losses Calculation - Impact of projects on grid losses

For the purposes of the CBA, the variation of losses due to a given interconnect project and relevant reinforcements has to be calculated. [7] is the reference document about this subject and have done under the Med-TSO work. Hereinafter the description of the adopted guidelines.

[15] Transparency suggests us to mention that Egypt and Israel did not supply data. MEDTSO thanks ESO, the Bulgarian TSO for the cooperation.

In line with ENTSO-E definitions, to calculate the difference in energy losses [MWh] associated to each project, and the related monetization, the losses have to be computed in two different simulations with the help of network studies: one with and one without the interconnection project and relevant internal reinforcements (clustering). A sufficient quality of the amount of calculated losses is obtained, if at least the following requirements are met:

1. Losses are representative for the relevant geographical area;
2. Losses are representative for the relevant period of time;
3. Market results (generation dispatch pattern) used for each simulation.

Total losses included both the internal losses in each grid (each country) due to the new project and also the losses in the new interconnection line/cable.

The assessment of annual losses is performed in two different ways:

a) for the interconnection: considering the 8760 h flows from the Market Studies;
b) for internal national grids: considering the network studies based on the PiTs selected for the Market Studies.

4.2.3.1 Losses in the interconnection lines (HVDC only)

Market studies provide hourly time series of exchange among countries for each Med-TSO 2030 scenario and for each new interconnection project, and also for the Reference case, which does not consider any new interconnection.

In case the interconnection project is AC, it should be considered as internal network of each country up to the border point (actual physical border point or conventional border if in the sea). In this case, losses in the interconnection are taken into account in the calculation of the internal losses (see paragraph 4 below).

4.2.3.1.1 Power and energy aspects

Since the Mediterranean Power System is weakly meshed, it can be assumed that physical flows on the interconnections are similar to commercial exchanges, and even absolutely equal for most of the projects to be assessed (loop flows are negligible).

In case of an increase of exchange capacity, losses strictly due to the new project are to be assessed from the difference of exchange before and after the new capacity, for each hour of the year. Thus, expected result is the variation of losses due to the new interconnection project and the associated additional capacity.

Market studies have provided hourly time series of exchange among countries for the 14 Clusters in each of the 4 scenarios. Those time-series shall be used directly for the borders where there is no existing interconnection: (e.g. MA-PT, DZ-ES, TR-EY, etc.), whereas for borders where interconnections exist (MA-ES), flows in the existing interconnection need to be deducted to obtain the additional flow in the new interconnection.

After selecting the exchanges hourly time series, the second stage is to convert flows into losses. For that, a third party provides formulas for several type of technology (A,B, etc.). Considering these formulas and the interconnections flows from the Market results an hourly time-series of additional losses can be computed for each technology (MW), and then added to obtain annual additional losses in Energy (MWh).

4.2.3.1.2 Monetization aspects

For the monetization of the additional losses, the cost of Electricity to be considered is the Marginal Cost, representing the cost of the cheapest Generation available to supply additional electricity needs for losses. The assessment of annual losses cost can be performed in two different approaches:

a) considering both hourly additional losses and hourly Marginal cost;
b) or, in a simplified way, considering only annual additional losses (in Energy) and average annual Marginal cost.

Since implementation of the above approached with several examples, doesn't show significant difference in the results, it is assumed that the simplified method is the preferred one

Finally, it is to be considered that Marginal costs are in general different in the two bordering countries, especially when the improvement of exchange capacity provides significant benefit.

Since rules for providing the losses shall be agreed by the involved TSO (or investors) in a later stage, it can be assumed for this current assessment that losses on the interconnection are monetized by considering the average value of the two bordering Marginal costs. This can be assimilated to a scheme where each TSO provide 50% percent of the total losses from his own national market.

Therefore, the monetization of the new HVDC interconnections will be calculated for each scenario as the delta losses multiplied by the average annual marginal Cost for the two countries interconnected.

4.2.3.2 Internal losses in each country (including losses on AC interconnections)

For the internal grid, the assessment of the variation of losses shall be performed by considering the results of Network studies, while Market studies are performed by considering only one node by country. In case the interconnection project is AC, losses in the interconnection are taken into account in the internal losses, considering the interconnection up to the border as internal network of each country.

4.2.3.2.1 Power aspect

Therefore, in case of the Med-TSO Network studies, for all PiTs of each cluster the losses (in MW) in two different situations are to be computed:

A) one with the project and the relevant internal reinforcements (results in MW);

B) other without the project and the relevant internal reinforcements (results in MW).

To perform these simulations, an adjustment of generation by country has to be done when the interconnection is open (not considered). When the situation B) does not allow maintaining international exchange due to a lower transfer capability, exchanges have to be reduced to match with the existing capacity. In this case, the way to compensate the load-generation balance is most important since its localization is expected to impact the losses. In order to compensate in a relevant way taking into account the global Merit order, the best way is to use the results of the Market studies.

The network simulation is performed considering a regional perimeter: as the following example regarding the assessment of the project between Iberia and Maghreb.

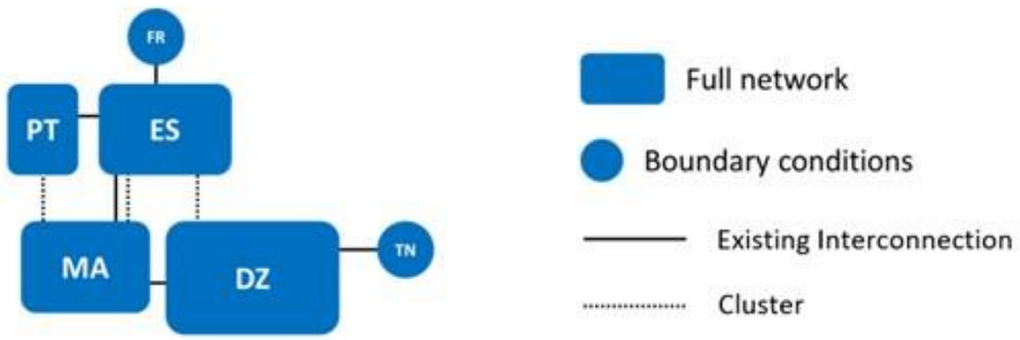


Figure 11: Example of regional perimeter to be considered in the internal grid losses calculation in western corridor.

In this case, the variation of internal losses is assessed in all the 'Full network' countries, i.e., Portugal, Spain, Morocco and Algeria. This means that, even if a part of the compensation takes place in France or in Tunisia, it is assumed that this variation is not considered for the losses assessment. For each PiT, the losses in case A) and in case B) shall be provided. The variation of losses shall be given with the sub-detail country by country.

Finally, the Variation in Losses [MW] will be calculated by the difference in the situations A) and B) for each PiT.

4.2.3.2.2 Energy aspect

After calculation of losses with and without the project and the related internal reinforcements for each PiT of each project, the annual energy dissipated in losses.

Since each PiT can be considered as an example, or a sample, of all the situations, the main issue is the weight to be associated to each PiT to convert from power to energy. Additionally, the number of PiTs being low (maximum 9 for each project) and mixing case in all of the 4 scenarios, it is not possible to calculated a variation of losses for each scenario and it is assumed that all the PiTs are considered when computing the variation of losses (one common value for all 4 scenarios).

It can be done by the following methods:

1. If available, the time percentile (hours of the year) that each PiT represents and multiply it with the delta losses calculated for their country for this PiT, to calculate the losses in MWh (time percentile could also be 0 if a PiT should be completely excluded from the calculation of losses);
2. If not available, all the PiTs analysed shall be considered with equal weight and the median value of delta losses calculated country by country for all Pits to obtain the estimated variation of internal losses due to the interconnection project.

For both methods, it is important to note for the conversion form Power to Annual Energy, that a new interconnection project does not provide any additional losses when exchanges are possible without this new project. The following figure shows as an example, the duration curve of exchange between Country A and Country B with the existing interconnection.

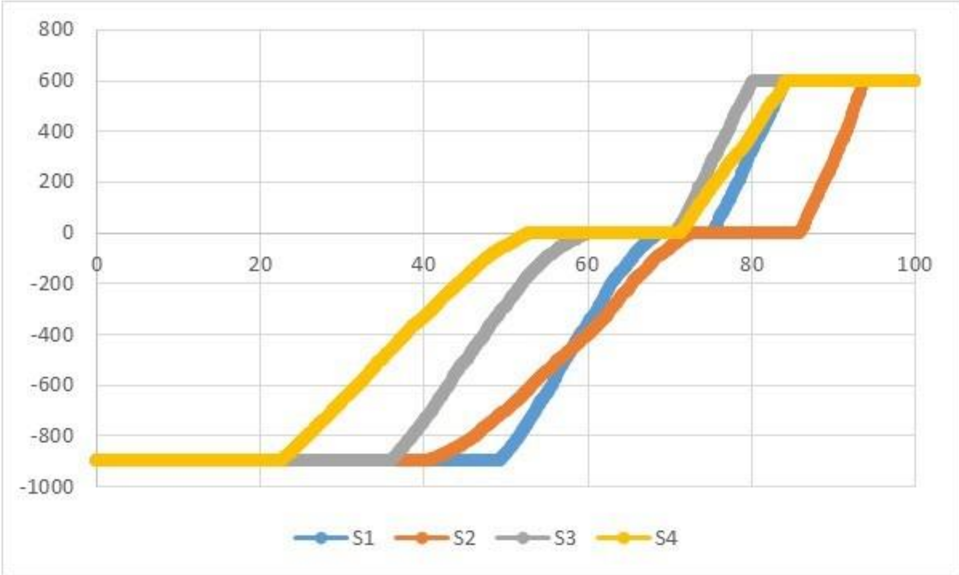


Figure 12. MAES exchange duration curve (as an example).

In this example, the interconnection is saturated around 40% of the time. This means that any new interconnection cannot provide internal variation of losses more than 40% of the year.

In the case of the method 2, the market studies provide the number of saturation hours of the interconnection for each new project and each scenario, to be considered for assessing the annual energy. In the case of the method 1, the cumulative number of hours shall not exceed what is to be considered in the method 2.

The following figure shows as an example the saturation hours for the Portugal – Morocco Cluster in the Scenario 1:

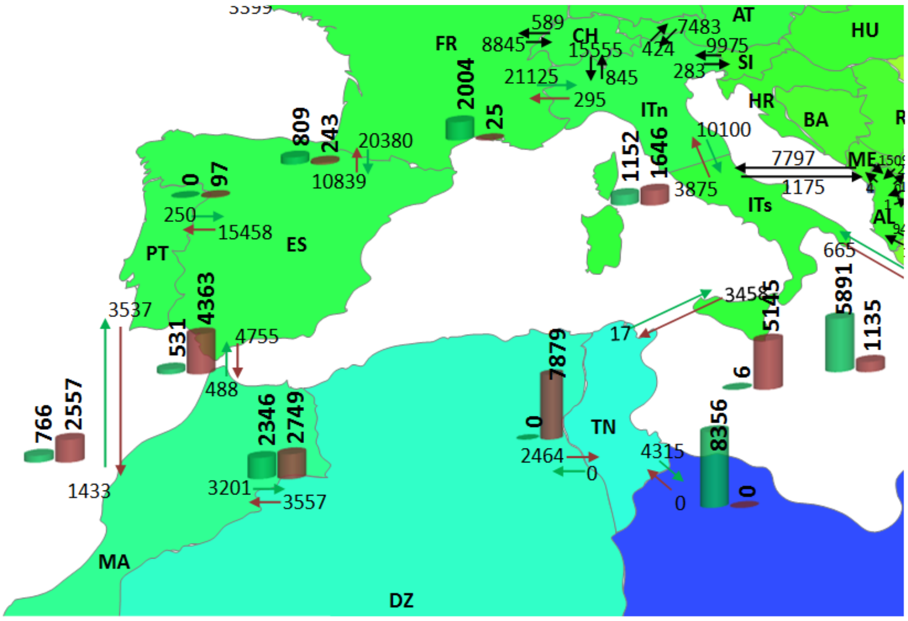


Figure 13. Saturation hours MA-PT Scenario 1 (as an example).

In this case, saturated hours are 2557 from Portugal to Morocco and 756 from Morocco to Portugal. Consequently, annual energy of the internal losses for this Cluster in the Scenario 1 shall be, when using the method 2, the average value of delta losses calculated for all 9 PiTs multiplied by 3313 hours.

At this stage, it is important to keep the annual sub-detail by country since it is useful for the monetization. Therefore, the Variation in Losses [MW] for all PiTs calculated by Network Studies shall be converted to annual variation in losses [MWh] in each grid according to one of the methodologies referred above.

The TSO can used other more sophisticated or simplified methods that they consider appropriate for their System, taking in to account their best estimation of the grid losses.

4.2.3.2.3 Cost aspect

For the monetization of the Annual Variation of Losses in the countries**,** it is proposed to use the Annual Average value of Marginal Cost for each one of the 4 Scenarios, for each country, as provided by the Market Studies.

Starting from the previous annual result in Energy for each project (only one value for all 4 Scenarios), sub-divided by countries, those energies shall be multiplied by the relevant marginal cost, to obtain the cost of variation of internal losses.

Therefore, the monetization of the Annual Variation of internal Losses in the countries will consist of the product of the energy of the country A multiplied by the Annual Average Marginal for country A (considering the interconnection) for each one of the 4 Scenarios (applicable for the other countries)

4.2.4 CBA Methodology

The CBA methodology summarized in this section is formulated in the Deliverable Report 2.2.4: Description of Cost Benefit Analysis Methodology for transmission project assessment [7] and it has been elaborated by the Working Group on Economic Studies and Scenarios (WG ESS) as Deliverable 2.2.4 within the Mediterranean Project. The Med-TSO Members agreed to adopt a methodology derived from the ENTSO-E proposal submitted to ACER in July 2016 and based on Regulation (EU) 347/2013 (guidelines for trans-European energy infrastructure). It sets out the Med-TSO criteria for the evaluation of costs and benefits of a transmission project, all of which stem from ENTSO-E practice based on European policies on market integration, security of supply and sustainability.

The goal of the project assessment is to characterize the impact of transmission projects, both in terms of added value for society (increase of capacity for exchanges of energy and balancing services between market areas, RES integration, increased security of supply) as well as in terms of costs. In order to ensure a full assessment of all transmission benefits, some of the indicators are monetized, while others are quantified in their typical physical units (such as tons or GWh). A general overview of the indicators used for project assessment is included in the Figure 9 below.

The set of common indicators, forming a complete and solid basis for project assessment across the Mediterranean is summarized below. The multi-criteria approach highlights the characteristics of a project and gives sufficient information to the decision makers.

The various KPIs contribute to the CBA [7], [8] which is performed scenario by scenario. The KPIs are: B1-Socio-economic welfare (SEW) [M€/y], B2-RES integration [MW/y], B3-Variation in CO_2 emissions [kT/y], B4-Variation in losses [M€/y], [GWh/y], B5a-Security of supply [MWh/y], B5b-SoS System Stability, C1 Total project expenditures [M€], S1 Environmental impact, S2 Social impact, S3 Other impacts.

The following pattern is adopted for each project, with the following meaning of the indices:

- **B1. Socio-economic welfare (SEW)** is the ability of a project to reduce congestion by facilitating cross border trading in an economically efficient manner.
- **B2. RES integration**: is the ability minimize curtailments and therefore to facilitate the RES integration. This indicator is economically included in the calculation of SEW but also displayed separately being the RES integration one key targets.
- **B3. Variation in CO_2 emissions** it derives from B1 and B2. This indicator is economically included in the calculation of SEW but also displayed separately being the RES integration one key targets
- **B4. Variation in losses** indicates the efficiency of the transmission system.
- **B5a & B5b. Security of supply. Respectively**
    - Adequacy to meet demand is the contribution of the project to increase the ability of a power system to cover the demand, taking into account the variability of climatic effects on demand and on forecasts of renewable energy sources production.
    - System stability is the effect of the project on the ability of a power system to guarantee a reliable supply of electricity taking into account the possible occurrences of system disturbances and faults.
- **C1. Total project expenditures** are based on prices used by each TSO and rough estimates on project consistency (e.g. km of lines). It includes all costs for deploying the project (material, execution, provisional expenditures, dismantling, O&M, etc.). The more the project is mature the more accurate should be the calculation. Costs for losses are not part of the total project expenditure, as the losses are reported separately by the indicator B4.
  The level of information about expected project costs depends on the status of the project. Therefore reporting of costs shall be done using the best information available, whilst ensuring consistency of assumptions and thus comparable cost figures.

  Costs shall be estimated as follows:

  a. Identify the standard investment costs to define the standard project costs.

  b. Project costs may be higher or lower than the standard investment costs. In this case, the project promoters define a project-specific complexity factor (if project costs equal the standard investment costs, the complexity factor is equal to 1) to account for the deviation from standard investment costs.

Residual impact is defined as follows:

As far as environmental and social mitigation costs are concerned, the costs of measures taken to mitigate the impacts of a project should be included in the project cost (indicator C1). Some impacts may remain after these mitigation measures are implemented. These residual impacts are accounted for by and included in indicators S1, S2, and S3. This split ensures that all measurable costs are taken into account, and that there is no double accounting between these indicators.

- **S1. Environmental impact** is the project impact as assessed through preliminary studies and measures how the project meets the environmental sensitivity associated with the project. S1 has been mostly used in the analysis include in the present report as a qualitative indicator, but in case it is quantified it can be expressed in terms of the number of kilometres that the routing of an overhead line or underground/submarine cable may run through environmentally 'sensitive' areas. This indicator only takes into account the residual impact or a project, i.e. the portion of impact that is not fully accounted for under C1.

- **S2. Social impact** is the measure of the project impact on the local population that is affected by the project, as assessed through preliminary studies as far as the social sensitivity is associated with the project. S2 has been mostly used in the analysis include in the present report as a qualitative indicator, but in case it is quantified it can be expressed in terms of the number of kilometres that the routing of an overhead line or underground/submarine cable may run through socially sensitive areas, such as areas of high touristic interest. This indicator only takes into account the residual impact of a project, i.e. the portion of impact that is not fully accounted for under C1.

- **S3. Other impacts**; this indicator lists the impact(s) of a project that are not covered by indicators S1 and S2, after potential mitigation measures defined when the project definition becomes more precise. These impacts may be positive or negative and will be included as a list in the assessment results. Impacts that are accounted for by indicators S1 or S2 shall not be included.

4.3 Project by project description

4.3.1 Common Models and Security criteria for Western Corridor Projects

For the horizon 2030, the security analysis performed with the merged full models of the systems of Portugal, Morocco, Algeria and Spain for the Points in Time (PiTs) selected. Each system represented by its transmission network model, was provided by the relevant TSOs (REN, ONEE, Sonelgaz and REE).

4.3.1.1 Models in common to Projects 1, 2 and 3

The Interconnection projects involving the Maghreb and Iberian Peninsula share the model described below:

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

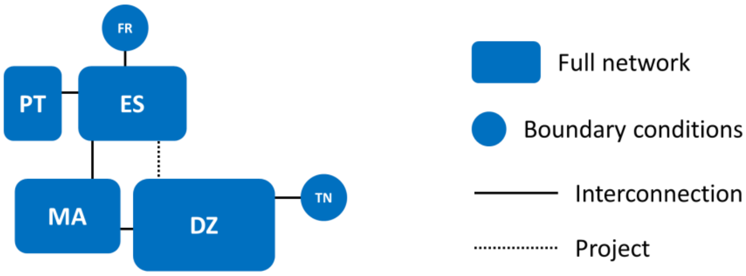


Table 1 – Participation of each of the electric systems involved in project of the western corridor

This means that the Portuguese, the Spanish, the Moroccan and the Algerian systems have been considered as represented by their full transmission network models as mentioned above, while France and Tunisia, have been considered as external buses with equivalent loads to simulate energy interchanges (boundary conditions).

4.3.2 Project 1 Morocco – Portugal. MAPT

Detailed description is provided in [13]

4.3.2.1 Project description and data acquisition

The project consists in a new interconnection between Portugal and Morocco to be realized through an HVDC submarine cable. This project is supported by the two governments, which launched several studies about this possible interconnection, some of them in elaboration at the present time.

The HVDC interconnection has a capacity of 1000MW and a total length of around 265km, of which approximately 220km will be in submarine cable. The HVDC interconnection consider the configuration of 2 circuits (bipolar converter) of 500 MW each, between TAVIRA substation of 400kV (PT) and BENI HARCHAN substation of 400kV (MA).

Generally speaking, the complementary characteristics in the power systems and economic conditions in the Mediterranean Countries can provide additional benefits over the time for the countries of southern 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 DARCHAOUL40 and SEHOUL_400
- A new 400kV OHL of 20 km between substations DAR.CHAOUL40 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	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 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:

a) single (1x1000 MW) pole converter
b) 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€.

4.3.5 Common Models and Security criteria for projects 4,5,6,7

4.3.5.1 Models

These Project assume the same grid model in terms of topology and completeness of grids summarized in the following.

The model defined for the first 3 projects of the central corridor is described in the table and figure below.

Full models	Boundaries
Italy IT	France FR
Tunisia TN	Switzerland CH
Algeria DZ	Austria AT
	Slovenia SI
	Montenegro ME
	Greece GR
	Libya LY
	Morocco MA

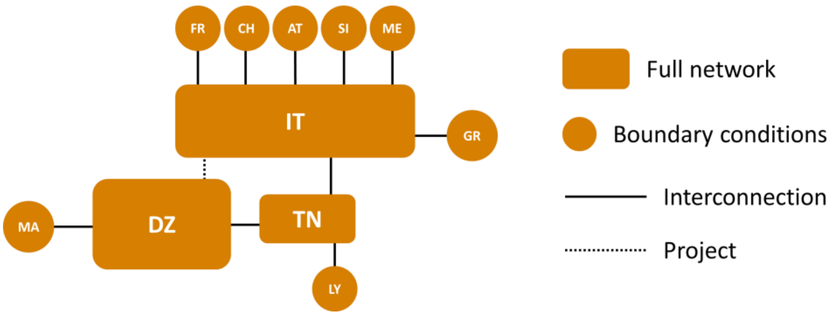


Table 3 – Participation of each of the systems involved in the projects of the central corridor

For this project, the Algerian, Tunisian and Italian systems have been fully modelled by their transmission network models. Boundary systems, i.e. Morocco, Libya, France, Switzerland, Slovenia, Montenegro and Greece, are considered as external buses with loads to simulate energy interchanges.

In the snapshots definition, 4 scenarios (S1, S2, S3 and S4) and seasonality (Winter/Summer) are distinguished. Models provided:

- For the Algerian system, a set of 8 models have been provided, corresponding with 4 scenarios (S1, S2, S3 and S4) and stationarity (Winter/Summer).
- For the Tunisian system, a set of 4 models have been provided, corresponding with 4 scenarios (S1, S2, S3 and S4)
- For the Italian system a set of 2 models have been provided, one for scenarios S1 and S2 and the other for scenarios S3 and S4.

In all models provided interconnected Areas are well identified. Generating technologies are identified in the ‘Owner’ field for Machines. Concerning merit order list, all generating units are considered with the same rank.

For the interconnection between **Algeria and Morocco** (boundary), two buses have been identified in Algerian networks. However, it is important to remark that one bus appears disconnected, since all the energy transfers between Morocco and Algeria are through another bus.

4.3.5.2 Power flow and security analysis

Being the Systems in common to the projects mentioned in 4.3.5.1, they assume the same security criteria and limits. The standard security criteria are reported in the following.

Algeria. For the Algerian system, the N-1 is focused on the transmission levels. Therefore, the branches considered for the N-1 analysis are only those at 220 kV and 400 kV. Also, overloads will only be checked for branches at 220 kV and 400 kV. No N-2 situations have considered for Algeria.

The tolerance for overload will be 0% for all branches, in N and N-1 situations independent of the season

Tunisia. For the Tunisian system, the N-1 has been focused on the transmission levels. Therefore, the branches considered for the N-1 analysis are only those at 150 kV, 225 kV and 400 kV. Also, overloads have been checked for branches at 150 kV, 225 kV and 400 kV.

The tolerance for overload will be 0% for all branches in N, and +20% in N-1 situations. Finally, no N-2 situations have considered for Tunisia.

Italy. For the Italian system, the N-1 has been focused on the transmission levels. Therefore, the branches considered for the N-1 analysis are only those at 150 kV, 220 kV, 400 kV and 500 kV. Also, overloads will only be checked for branches at 132 kV, 150 kV, 220 kV, 400 kV and 500 kV.

Concerning rates and tolerances, for lines and transformers, 1.2 times the rateA will be considered for Winter and 0.8 times the rate A for Summer. The tolerance for overloads in lines will be 0% for N and N-1 situations. The tolerance for overloads in transformers will be 0% for N and +10% for N-1 situations.

Finally, the set of N-x outages is defined by considering simultaneous outage of each couple of branches with a degree of separation from the interconnections less or equal to two.

4.3.6 Project 4 Algeria – Italy (DZIT)

Detailed description is provided in [16]

4.3.6.1 Project description and data acquisition

The project consists in a new interconnection between Algeria and Sardinia to be realized through an HVDC submarine cable, with a carrying capacity of 1000 MW and a total length of around 350 km. The maximum depth for the installation of the undersea cable will be over than 2000m.

The study of potential befits project has been proposed by Sonelgaz and Terna in the framework of MedTSO studies.

A previous preliminary evaluation has been done in the context of Paving the way activities.

The HVDC link will be between south of Sardinia (IT) and North – Est of Algeria (Cheffia region), the connection of AC/DC substation to the national grid (Cheffia substations) will be performed through 2x50 km of 400 kV OHL.

The system defined for project DZTN is described in 4.3.5.1.

4.3.6.2 Assessment of reinforcements

For the interconnection project between Algeria and Italy, no severe overloads have been detected due to the new interconnection for neither the Italian or Tunisian systems. Therefore, no reinforcements were defined for neither of them.

In the case of the Algerian system, some overloads are detected in the area between Ramdane Djamel and Berrahl substations. These overloads appear in 220 kV network under the outage of 400 kV circuits Ramdana -Berrahal. To solve this situation, a single reinforcement has been defined to be analyzed. This reinforcement consists of doubling the 400 kV 65 km circuit between Berrahal and Ramdana.

The figure shows the map of the projected interconnection (yellow line), and corresponding reinforcements (green line).

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 has been estimated to 848M€.

4.3.7 Project 5 Tunisia – Italy (TNIT)

Detailed description is provided in [17]

4.3.7.1 Project description and data acquisition

The project consists in a new interconnection between Tunisia and Italy (Sicily) to be realized through an HVDC submarine cable. The realization of the project is supported by the Italian and Tunisian Governments to increase the interconnection capacity of the Euro-Mediterranean system. Moreover, the project will contribute to reduce present and future limitations to the power exchanges on the northern Italian border under specific conditions, and therefore it will allow to increase significantly the transmission capacity and its exploitation by at least 500 MW on that boundary.

The system defined for project TNIT is described in 4.3.5.1

Based on the recent pre-feasibility study, the connection nodes have been preliminary fixed at:

- On the Tunisian side: the new 400 kV substation in the area of Cap Bon; at the 400 kV existing electrical substation of Mornaguia. The converter station shall be located in the peninsula area of Cap Bon and n.2 new 400kV OVHL will be necessary to link the new substation with the existing electrical 400 kV internal grid. The need of other synchronous compensator in the area of Cap Bon needs to be evaluated and is depending on the technology of the converter station.
- On the Italian side: at the 220 kV bus-bar of the existing electrical substation of Partanna. The converter station shall be located in an area close to this substation.
- The new 380 kV double circuit line Chiaramonte Gulfi - Ciminna (currently under permitting), further local reinforcements of the existing high voltage grid and the installation of any synchronous compensator in Sicily (still under evaluation) should be the necessary internal reinforcements. The project is under feasibility study phase: (Network Study, Terrestrial and Marine Survey Study and Environmental and Social Impact Study).

4.3.7.2 Assessment of reinforcements

Additional reinforcements identified in the Tunisian System, consist in the reinforcement of 400kV OHL line Mornaguia – Hawaria to 3 bundle. The figure shows the maps of projected interconnection (yellow line), and corresponding reinforcements (green line).

4.3.8 Project 6 Tunisia – Italy 2 (TNIT2)

Detailed description is provided in [18]

4.3.8.1 Project description and data acquisition

The project involves the reinforcement of the first interconnection (600 MW) between Tunisia and Sicily to be realized through an HVDC submarine cable. The project may contribute to reduce present and future limitations to the power exchanges on the northern Italian border under specific conditions, and therefore it may allow to increase significantly the transmission capacity and its exploitation by on that boundary.

The model defined for project TNIT2 is described in 4.3.5.1.

In all models provided interconnected Areas are well identified. Generating technologies are identified in the 'Owner' field for Machines. Concerning merit order list, all generating units are considered with the same rank.

Certain particularities in the models provided for the three systems involved in the project are mentioned below:

Connections between Algeria and Tunisia are well defined in both sides. For the interconnection between Italy and Tunisia, bus HAWARIA has been identified in the Tunisian networks, and bus XPA_EL9I in the Italian networks.

Projects TNIT2 involve two HVDC links between Tunisia and Italy. Buses in the Tunisian side (HAWARIA) and the Italian side (XPA_EL9I) have been identified.

4.3.8.2 Power flow and security analysis

The criteria agreed to run the power flow and security analysis for the different snapshots are in common with the projects of the central corridor reported in 4.3.5.2.

Regarding the loss of generating units, the energy lost will come from the Moroccan interconnection, until rate. Then, if it is necessary, the rest of the energy lost will come from Italy through Tunisia, via the TNIT interconnection.

Finally, no N-2 situations have considered for Algeria.

4.3.8.3 *Assessment of reinforcements*

For this project, the only reinforcement considered in the Tunisian system is the addition of a new 400kV circuit between Mornaguia and Oueslatia (140 km) and corresponding 400/220kV transformers at the Oueslatia substation.

The figure shows the map of the projected interconnection (yellow line), and corresponding reinforcements (green line).

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 has been estimated to 583M€.

4.3.9 Project 7 Algeria – Tunisia (DZTN)

Detailed description is provided in [19]

4.3.9.1 *Project description and data acquisition*

The project consists in a new interconnection between Algeria and Tunisia, with a capacity of 700 MW.

It is due to the important hours of saturation that were detected in the preliminary market simulations that this cluster was added. Physically, it consists on a second 400 kV OHL from the substation Jendouba in Tunisia to the substation Chefia in Algeria.

The model defined for project DZTN is described in 4.3.5.1.

For this project, the Algerian and Tunisian systems have been considered as full represented by their transmission network models. Boundary systems, i.e. Morocco, Italy and Libya, are considered as external buses with loads to simulate energy interchanges.

In the snapshots definition, 4 scenarios (S1, S2, S3 and S4) and stationarity (Winter/Summer) are distinguished. Models provided:

- For the Algerian system, a set of 8 models have been provided, corresponding with 4 scenarios (S1, S2, S3 and S4) and stationarity (Winter/Summer).
- For the Tunisian system, a set of 4 models have been provided, corresponding with 4 scenarios (S1, S2, S3 and S4)

In all models provided interconnected Areas are well identified. Generating technologies are identified in the 'Owner' field for Machines. Concerning merit order list, all generating units are considered with the same rank.

Connections between Algeria and Tunisia are well defined in both sides. For the interconnection between Italy and Tunisia, bus HAWARIA has been identified in the Tunisian networks.

For the interconnection between Algeria and Morocco (boundary), two buses have been identified in Algerian networks as part of the Moroccan network. However, it is important to remark that one bus appears disconnected, since all the energy transfers between Morocco and Algeria are through another bus.

Project DZTN involves a second AC-OHL circuit for the 400 kV interconnection between Tunisia and Algeria. Buses in the Algerian side (CHEFIA) and the Tunisian side have been identified.

4.3.9.2 *Assessment of reinforcements*

No remarkable overloads associated to the new interconnection were identified in the Algerian system, thus no reinforcements were defined for Algeria. Tunisia has been the only system that has set reinforcements to be considered.

The energy interchange with Algeria through the existing and projected interconnection undergoes some overloads in the 220 kV network. To overcome this, the 220 kV interconnection between Algeria and Tunisia is opened, thus the energy tends to flow through the 400 kV subnetwork. To reinforce it, next new devices are considered:

- New 400 kV circuit Oueslatia - Mornaguia (140 km)

- New 220/400 kV transformer at Oueslatia substation

In addition, a reinforcement is needed to evacuate the power at Jendouba substation. Two different alternatives have been considered, 1) a new 400 kV circuit between Jendouba and Oueslatia substations, or 2) a new 400 kV circuit between Jendouba and Mornaguia substations. Both alternatives provide a new 400 kV corridor for the energy of the interconnection, and results obtained in the security analysis are quite similar, solving most of the overloads due to the new interconnection. Comparing them, first alternative (400 kV Jendouba - Oueslatia) seems to be a bit more effective, since the second alternative (400 kV **Jendouba - Mornagui**) is not capable of solving some of the problems in the N-1 situations, such as 220 kV **Jendouba** – Kef (PiT 4), or 200 kV **B.M.Cher – Mornagui**, **Mnihla – Chotrana** and **Naassen - Mornagui** (PiT 5).

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 has been estimated to 155M€.

4.3.10 Project 8 Tunisia – Libya – Egypt (TNLYEY)

Detailed description is provided in [20]

4.3.10.1 Project description and data acquisition

The project consists in a new interconnection across Tunisia, Libya and Egypt.

Tunisia has been connected to Libya's network in HVAC since 2002 with three 220 kV HVAC lines. However, these connections remain out of service due to stability problems and high power oscillations caused by the Mediterranean eastern power system (Libya and Egypt). Egypt and Libya are interconnected by one 220 kV HVAC line that is in service since 1998.

The model defined for project TNLYEY is described in 4.3.5.1.

For this project, the Tunisian and Libyan systems have been considered as full represented by their transmission network models. Boundary systems, i.e. Algeria, Italy and Egypt, are considered as external buses with loads to simulate energy interchanges.

In the snapshots definition, 4 scenarios (S1, S2, S3 and S4) and stationarity (Winter/Summer) are distinguished. Models provided:

- For the Tunisian system, a set of four (4) models have been provided, corresponding with 4 scenarios (S1, S2, S3 and S4)
- For the Libyan system a unique model has been provided.

4.3.10.2 Assessment of reinforcements

The main outcomes of the contingency analysis for each system involved in the project could be summarized to the following:

Tunisia:

The energy interchange with Libya through the projected 400 kV interconnection comes down to the 220 kV network at the Bou Chema substation. This fact may undergo some overloads at the 220 kV network. To overcome this, it is planned to include new 400 kV circuits that takes most of the energy interchanged between the north and the south. Reinforcements considered are:

- New 400 kV circuit between **Bou Chema** and **Oueslatia**.
- New 220/400 kV transformer at **Oueslatia** substation.
- New 400 kV circuit between **Oueslatia** and **Mornaguia**.
- New 220/400 kV transformer at **Bou Chema** substation.

Libya. Relevant overloads detected at the 220 kV network are due to the fact that those cables have no ampacity enough. To overcome this, all overloaded 220 kV are planned to be replaced with better lines conductor specification (superconductor lines) as shown in the table below which already operating in Libya transmission network.

Next figures show the maps of interconnections, both existing (dashed-yellow line) and projected (yellow line), and corresponding reinforcements (green line).

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 has been estimated to 540M€.

4.3.11 ■ Project 9: TREY (Turkey - Egypt)

Detailed description is provided in [21]

4.3.11.1 Project description

The project is located in eastern Mediterranean and consists of a DC submarine cable between Turkey and Egypt and is promoted by TEIAS and EETC (under the umbrella of the studies carried out by Med-TSO within the Mediterranean Project I).

The project is planned as an alternative to existing north-south corridor passing through Turkey, Syria, Jordan and Egypt. The main driver of the project is to develop a new corridor in the eastern Mediterranean region and to increase renewable energy integration in the region. Estimated capacity is about 3000MW.

4.3.11.2 Security Analysis

For the horizon 2030, only the system of Turkey involved in the project was considered as fully represented by its transmission network models which was provided by the relevant TSOs (TEIAS) for 2 common Points in Time (PiTs) representing the summer and winter peaks, while boundary systems of Greece, Bulgaria, Syria were considered as loads on border buses to simulate energy interchanges. The system of Egypt was also considered as boundary, due to the lack of data provided by the relevant TSO (EETC).

Based on the results of the Market Analysis for this project, a total number of nine Points in Time (PiT) have been defined with respect to the following criteria:

- Simultaneous high saturation on the interconnections (on both directions) representing possibly a large time percentile
- Extreme (high/low) load in the countries involved in the project
- High/low RES production of different categories (PV, RES) in the countries involved in the project
- High/low nuclear production in Turkey

The system model of Turkey was adjusted for each PiT in terms of load and generation. For the 9 models security analysis (N, N-1) was performed, with the aim to identify the need of possible internal reinforcement related to the project. The criteria followed for the Turkish System are the same as for the other projects involving Turkey. Additionally, a set of N-2 outages has been specified, considered as relevant for the project.

4.3.11.3 Assessment of reinforcements

The security analysis identified in the Turkish system several reinforcements related to the project. To reinforce Turkish grid in the vicinity of TREY project's connection point, connection of planned 400kV Kozan – Sanko OHL should be modified by connecting this OHL to Misis OSB substation. After modification process, Kozan – Sanko OHL would be operated as 400kV Kozan – Misis OSB OHL and 400kV Misis OSB – Sanko OHL. Additionally, replacement of existing 400kV 2bundle Adana – Bastug, Toscelik – Bastug, Erzin – Toscelik, and Erzin – Toscelik OHLs with 3bundle conductors are required to reinforce the region. 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 has been estimated to 2.9 B€.

4.3.12 ■ Project 10: TRIS (Turkey - Israel)

Detailed description is provided in [22]

4.3.12.1 Project description

The project is located in eastern Mediterranean and consists of a DC submarine cable between Turkey and Israel. It is promoted by TEIAS and IEC (under the umbrella of the studies carried out by Med-TSO within the Mediterranean Project I).

The main driver of the project is to develop a corridor between Turkey and Israel to create trade possibilities and to increase renewable energy integration in the region. Estimated capacity is about 2000MW.

4.3.12.2 Security Analysis

For the horizon 2030, only the system of Turkey involved in the project was considered as fully represented by its transmission network models which was provided by the relevant TSOs (TEIAS) for 2 common Points in Time (PiTs) representing the summer and winter peaks, while boundary systems of Greece, Bulgaria, Syria, were considered as loads on border buses to simulate energy interchanges. The system of Israel was also considered as boundary, due to the lack of data provided by the relevant TSO (IEC).

Based on the results of the Market Analysis for this project, a total number of nine Points in Time (PiT) have been defined with respect to the following criteria:

- Simultaneous high saturation on the interconnections (on both directions) representing possibly a large time percentile
- Extreme (high/low) load in the countries involved in the project
- High/low RES production of different categories (PV, RES) in the countries involved in the project
- High/low nuclear production in Turkey

The system model of Turkey was adjusted for each PiT in terms of load and generation. For the 9 models security analysis (N, N-1) was performed, with the aim to identify the need of possible internal reinforcement related to the project. The criteria followed for the Turkish System are the same as for the other projects involving Turkey.

Additionally, a set of N-2 outages has been specified, considered as relevant for the project.

4.3.12.3 Assessment of reinforcements

The security analysis identified in the Turkish system only one reinforcement related to the project. To reinforce Turkish grid 400kV Mersin – Adana OHL is required. Also replacement of existing 400kV 2bundle Toscelik – Bastug OHL with 3bundle conductors is needed to reinforce the region.

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 has been estimated to 1.7B€.

4.3.13 ■ Project 11: EYJO (Egypt - Jordan)

Detailed description is provided in [23]

4.3.13.1 Project description

The project is relating to add a new interconnection between Jordan and Egypt, which will lead to double the current capacity between Egypt-Jordan to be 1100 MW. The project is promoted by NEPCO and EETC (under the umbrella of the studies carried out by Med-TSO within the Mediterranean Project I).

Jordan and Egypt are electrically interconnected since 1998 via a 13km, 400kV submarine cable across the Gulf of Aqaba to Taba, with an exchange capacity of 550MW. Egypt and Jordan are part of the 8 countries interconnection, including also Syria, Lebanon, Turkey, Iraq, Palestine, and Libya.

The main driver of the project is to further increase the interconnection capacity between Egypt, and Jordan to reach 1100 MW. This will enhance the integration of RES generation and increase grid stabilization, helping both countries to meet their load demand, with the positive effect of postponing investments in both generation and transmission.

4.3.13.2 Security Analysis

For the horizon 2030, only the Jordanian system involved in the project was considered as fully represented by its transmission network model, which was provided by the relevant TSOs (NEPCO) for 2 common Points in Time (PiTs) representing the summer and winter peaks. As far as the grid models adopted the Syrian system has been fully simulated (in the current status, the Egyptian one through an equivalent network. For the systems of Lybia an and Plalestine boundary systems have been considered as border buses to simulate energy interchanges.

Based on the results of the Market Analysis for this project, a total number of seven Points in Time (PiT) have been defined with respect to the following criteria:

- Simultaneous high saturation on the interconnections (on both directions) representing a high time percentage especially the period where Jordan Imports/Exports energy to both Syria and Egypt.
- Extreme (high/low) load in the countries involved.
- High/low RES production of different categories (PV, wind) in both interconnected countries.
- High/Low Nuclear new production in Jordan/Egypt.
- High/Low new primary energy generation resources in southern part of Jordan (Oil Shale and Coal).
- Wheeling from Egypt to Syria through Jordan.

The merged system model of Jordan and equivalent models of Egypt, Lybia and Syria were adjusted for each PiT in terms of load and generation. For the 7 merged models security analysis (N, N-1) was performed, with the aim to identify the need of possible internal reinforcement related to the project. The criteria followed are summarized as follows:

In the Jordanian system contingencies were considered only on the transmission level (400kV), while both 132 kV and 400 kV voltage levels were monitored. For the Egyptian system, security analysis focused only on the transmission level (400kV and 500kV). Concerning rates and tolerances, for the Jordanian system Rate B was considered for all PiTs, while a tolerance for overload of -10% was considered for N and of 0% for N-1 situations for all branches. For the Egyptian system, Rate A was considered for all PiTs, while a tolerance for overload of 0% was considered for N and N-1 situations. Regarding the loss of generating units, for the Jordanian system 10% of the energy lost was considered to be compensated from local (Jordanian) generating units and 90% from Egypt and for the Egyptian system from local generating units. No N-2 situations were considered for both systems.

4.3.13.3 Assessment of reinforcements

The main outcomes of the security analysis for each system involved in the project are summarized to the following:

- For the Jordanian system, considering possible overloads in the path of the interconnection, a new reinforcement is proposed consisting in doubling the existing 400 kV double circuit between MAAMN and ATP400 (4 circuits between MAAMN and ATP400.
- For the Egyptian system a new reinforcement is proposed consisting in doubling the 500 kV circuit between O-MOUSA and TABA400 and the 500/400 kV transformer at TABA substation.

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 has been estimated to 198M€.

4.3.14 ■ Project 12: JOSYTR (Jordan - Syria - Turkey)

Detailed description is provided in [24]

4.3.14.1 Project description

The project is located in eastern Mediterranean and consists of two new interconnections: one between Jordan and Syria and one between Syria and Turkey, to be realized through AC overhead lines and an HVDC Back-to-Back station in Turkey. The project is expected to double the current transfer capacity to become 1600 MW between Jordan and Syria and 1200 between Turkey and Syria. The project is promoted by NEPCO and TEIAS (under the umbrella of the studies carried out by Med-TSO within the Mediterranean Project I).

Jordan, Syria, and Turkey are electrically connected by a 400 kV grid, with existing capacity of 600 MW (Turkey-Syria) and 800 MW (Jordan-Syria). These countries are part of the 8 countries interconnection, including also Egypt, Lebanon, Iraq, Palestine, and Libya.

The main driver of the project is to further increase the interconnection capacity between Syria, Turkey, and Jordan by another 800 MW between Jordan and Syria and 600 MW between Turkey and Syria. This will allow mainly meeting the Syrian demand and to integrate more renewable resources and base load units in the region.

4.3.14.2 Security Analysis

For the horizon 2030, the systems of Jordan and Turkey involved in the project were considered as fully represented by its transmission network models which was provided by the relevant TSOs (NEPCO and TEIAS respectively) for 2 common Points in Time (PiTs) representing the summer and winter peaks. As far as the grid models adopted the Syrian system has been fully simulated (in the current status), the Egyptian one through an equivalent network. For the systems of Libya and Palestine boundary systems have been considered as border buses to simulate energy interchanges.

Based on the results of the Market Analysis for this project, a total number of nine Points in Time (PiT) have been defined with respect to the following criteria:

- Simultaneous high saturation on the interconnections (on both directions) representing a high time percentage especially the period where Jordan and Turkey Imports/Exports Energy to both Syria.
- Extreme (high/low) load in the countries involved.
- High/low RES production of different categories (PV, wind) in interconnected countries.
- High/Low Nuclear new production in Jordan and Turkey

The merged system model of Jordan and Turkey and equivalent model of Syria were adjusted for each PiT in terms of load and generation. For the 9 models security analysis (N, N-1) was performed, with the aim to identify the need of possible internal reinforcement related to the project. The criteria followed for the Turkish System are the same as for the other projects involving Turkey. For the Jordanian and Syrian systems criteria followed are summarized as follows:

For the Jordanian system contingencies were considered only on the transmission level (400kV) and both 132 kV and 400 kV voltage levels were monitored, while for the Syrian system security analysis focused only on the transmission level (400kV and 220kV). Concerning rates and tolerances, for the Jordanian system Rate B was considered for all PiTs, while a tolerance for overload of -10% was considered for N and of 0% for N-1 situations for all branches. For the Syrian system, Rate A was considered for all PiTs, while a tolerance for overload of 0% was considered for N and N-1 situations. Regarding the loss of a generating unit, for the Jordanian system 10% of the energy lost was considered to be compensated from local (Jordanian) generating units and 90% was shared by Syria (10%), Egypt (50%) and Turkey (30%).

Additionally, a set of N-2 outages has been specified for the Turkish system, considered as relevant for the project, while no N-2 situations were considered for both systems of Jordan and Syria.

4.3.14.3 Assessment of reinforcements

The main outcomes of the security analysis for each system involved in the project are summarized to the following:

- For the Jordanian system, since remarkable overloads associated with the new interconnection have been identified, no reinforcements were considered.
- For the Syrian network, a new reinforcement is proposed consisting in doubling the existing 400 kV double circuit between ADRA 2 and DIR-ALI (4 circuits between ADRAZ and DIR-ALI).
- For the Turkish network, most of the overloads detected during the security analysis are not considered relevant to the project. Two main relevant reinforcements were identified are replacement of the 2bundle OHLs with 3bundle conductors. Replacement of 400kV 2bundle Ataturk – Birecik OHL with double circuit 3bundle conductors and replacement of 400kV 2bundle Birecik HES – Birecik are required to reinforce the region.

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 has been estimated to 248M€.

4.3.15 Project 13: GRTRBG (Greece - Turkey - Bulgaria)

Detailed description is provided in [25]

4.3.15.1 Project description

The project consists in two new interconnections: one between Greece and Turkey and one between Bulgaria and Turkey to be realized through AC overhead lines. The project is promoted by IPTO, TEIAS and ESO (under the umbrella of the studies carried out by Med-TSO within the Mediterranean Project I).

Greece and Bulgaria are part of the Continental Europe Synchronous Area (CESA) to Turkey transmission corridor. Currently there is one interconnection between Greece and Bulgaria, one between Greece and Turkey and two between Bulgaria and Turkey. Total NTC values are 650 MW CESA to Turkey direction and 500 MW in the opposite direction. Two thirds of this NTC are presently allocated to the Bulgaria to Turkey connection and one third is allocated to the Turkey to Greece connection.

The second Greece to Bulgaria and the related strengthening of the 400 KV south East Bulgarian network which is under way, will help to increase future NTC to 1350 MW on CESA to Turkey direction and to 1250 MW on the opposite direction. The realization of the project is aiming to further increase the interconnection capacity between Turkey and the CESA (Continental Europe Synchronous Area) of about 1000MW.

4.3.15.2 Security Analysis

For the horizon 2030, the systems of Greece, Bulgaria and Turkey involved in the project were considered as fully represented by their transmission network models which were provided by the relevant TSOs (IPTO, ESO and TEIAS respectively) for 2 common Points in Time (PiTs), representing the summer and winter peaks, while boundary systems of Albania, Italy, FYROM, Serbia, Romania and Syria, were considered as loads on border buses to simulate energy interchanges.

Based on the results of the Market Analysis for this project, a total number of nine PiTs have been defined with respect to the following criteria:

- Simultaneous high saturation on the interconnections (on both directions) representing possibly a large time percentile
- Extreme (high/low) load in the countries involved in the project
- High/low RES production of different categories (PV, RES) in the countries involved in the project
- High/low nuclear production in Turkey

The 3 system models were adjusted for each PiT in terms of load and generation and then merged into one single model. For the 9 merged models, security analysis (N, N-1) was performed, with the aim to identify the need of possible internal reinforcement related to the project. The criteria followed are summarized as follows:

For the systems of Greece and Turkey, the security analysis focused only on the bulk transmission level (400kV), while for Bulgaria also the 220kV level was considered. Concerning rates and tolerances, for Greece different rates for both lines and transformers were considered for summer (rate B) and winter (rate A) PiTs, while a tolerance for overload of 0% was considered in both N and N-1 situations. For the Turkish system, rate B was considered for summer PiTs and rate A for winter, while a tolerance for overload of 0% was considered for N and of +10% for N-1 situations. For the Bulgarian System, rate A was considered as unique rate for both lines and transformers, while a tolerance for overload of 0% was considered for N and N-1 situations. Regarding the loss of a generating unit, the energy lost was considered to be compensated by the interconnections with FYROM in case of Greece, using the rest available generating units in case of Turkey and from the interconnections with FYROM, Romania and Serbia for Bulgaria.

Additionally, a set of N-2 outages has been specified by each TSO, considered as relevant for the project.

4.3.15.3 Assessment of reinforcements

As a general outcome of the security analysis, it can be summarized that most of the overloads identified, particularly those in the areas where the project is connected, can be resolved with generation redispatch.

More specifically, focusing on each of the systems involved, in Bulgaria most of the overloads identified in the Bulgarian system during the contingency analysis can be attributed to the lack of representation of the rest of the Balkan System in the model, particularly of the system of FYROM. The Balkan Systems are strongly interconnected and interdependent. As a result of that, in case of contingencies, some of the flows reported in the Bulgarian System are not realistic and in certain PiTs representing extreme cases, they can result in significant overloads. In addition, some of the overloads are relevant to convention adopted for the representation of future dispersed RES generation as concentrated in certain 400kV substations.

For the system of Greece two internal reinforcements were identified close to the border with Bulgaria and Turkey:

- a second double 400kV line between the 400kV substations of Nea Santa and Filippi
- a second double 400kV line between the 400kV substations of Thessaloniki and Lagadas

It should be stressed that in the analysis performed, the foreseen increase in the NTCs with the systems of Bulgaria and Turkey should be considered as a limiting factor affecting the need for internal reinforcements. More specifically, the NTC without the project from Greece/Bulgaria to Turkey is limited to 1350MW, expected to increase with the project to 1850MW, while in the opposite direction it is 1250MW expected to increase to 1750MW. Nevertheless, the flows in the interconnections identified in some the PiTs analysed, exceed significantly above mentioned limits. This is due to the fact that the three systems represent an interconnected triangle, situation which presents some difficulty in controlling the power flows in the interconnections to meet the values defined in the PiTs. Thus, as a general remark it should be stressed that the internal reinforcements identified are required only in case the NTCs increase exceeds the foreseen values.

For the Turkish network, most of the overloads detected by the security analysis are not considered as relevant to the project. To reinforce Turkish network and to overcome overloadings in the vicinity of GRBGTR project’s connection point, spare circuit of Verbena (Hamitabat) – Habibler OHL could be used. Verbena (Hamitabat) – Habibler OHL is being constructed as 400kV double circuit 160km OHL and spare circuit could be operated as Hamitabat – Alibeykoy OHL to reinforce region. Also replacement of existing 400kV 2bundle Hamitabat – Babaeski OHL with 3bundle conductors is required to reinforce the region.

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 has been estimated to 208M€.

4.3.16 Project 14: GRCYIS (Greece - Cyprus - Israel)

Detailed description is provided in [26]

4.3.16.1 Project description

The project referred to as Euro Asia Interconnector, consists of a HVDC VSC 500kV submarine cable for the interconnection of the systems of Greece, Cyprus and Israel. The link will have a capacity of 2000 MW and a total length of around 832 nautical miles/around 1541 km (approx. 314 km between Cyprus and Israel, 894 km between Cyprus and Crete and 333 km between Crete and Athens) and allow for reverse transmission of electricity. This project was promoted for TYNDP inclusion by a non-ENTSO-E member, complying with the EC's draft guidelines for treatment of all promoters. It is expected to end the Energy Isolation of Cyprus, the last member of the European Union which remains fully isolated without any electricity or gas interconnections. It will also create the electricity highway from Israel-Cyprus-Crete-Greece (Europe) through which the European Union can securely be supplied with electricity produced by the gas reserves in Cyprus and Israel as well as from the available Renewable Energy Sources, contributing at the same time to the completion of the European Internal market. Furthermore, it will promote the substantial development of the RES with the resulting reduction of the CO_2 emissions and offer significant economic and geopolitical benefits to the involved countries.

4.3.16.2 Security Analysis

For the horizon 2030, the systems of Greece and Cyprus involved in the project were considered as fully represented by their transmission network models which were provided by the relevant TSOs (IPTO and Cyprus TSO respectively) for 2 common Points in Time (PiTs) representing the summer and winter peaks, while boundary systems of Albania, Italy, Israel, FYROM, Bulgaria and Turkey were considered as loads on border buses to simulate energy interchanges. The system of Israel was also considered as boundary, due to the lack of data provided by the relevant TSO (IEC).

Based on the results of the Market Analysis for this project, only two Points in Time (PiT) have been defined with respect to the following criteria:

- High imports or exports particularly affecting the system of Cyprus
- Simultaneous high saturation on the interconnections (on both directions) representing a high time percentile
- Extreme (high/low) load conditions in the countries involved
- High/low RES production of different categories (PV, RES)

The 2 system models were adjusted for each PiT in terms of load and generation and then merged into one single model. For the 9 models security analysis (N, N-1) was performed, with the aim to identify the need of possible internal reinforcement related to the project. The criteria followed for the Greek System are the same as for the other projects involving Greece. For the system of Cyprus are summarized as follows:

Security analysis for the system of Cyprus focused only on the highest existing voltage level of 132 kV. Concerning rates and tolerances, rate A was considered as unique rate for both lines and transformers, while a tolerance for overload of 0% was considered N and +10% for N-1 situations. Regarding the loss of a generating unit, the energy lost was considered to be compensated by the rest available local generating units.

Additionally, a set of N-2 outages has been specified by each TSO, considered as relevant for the project.

4.3.16.3 Assessment of reinforcements

The main outcomes of the security analysis for each system involved in the project are summarized to the following:

- For the system of Greece, minor overloads observed are not considered critical and can be resolved by generation redispatch, thus no internal reinforcements were identified as relevant for the project.
- For the system of Cyprus for the horizon 2030, taking into account the reinforcements foreseen in the Ten Year Network Development Plan 2018-2027, no overloads were observed, thus no internal reinforcements were identified as relevant for the project.

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 has been estimated to 848M

4.4 Conclusions corridor by corridor.

For the purpose of the Network Studies, the 14 projects (or clusters) of the Mediterranean Project that were analysed above, were considered as distributed among 3 corridors, Western, Central and Eastern as presented in the following figure:

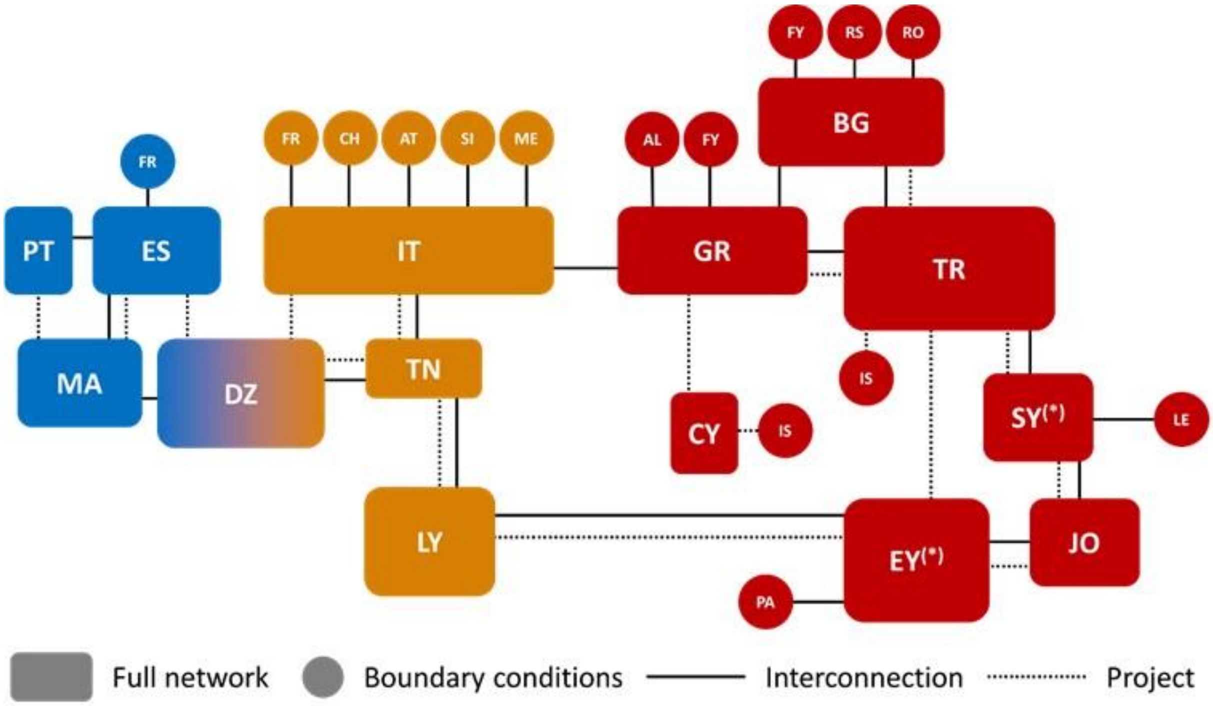


Figure 13 – Division of the Mediterranean systems in Corridors

The main conclusions of the security analysis performed for the projects of each corridor are presented below:

4.4.1 Western Corridor

The Western Corridor already implements the synchronous operation of two continents. Both shores are affected by ambitious plans of penetration of RES. These circumstances make the corridor candidate for important development in future on one side. On the other side the technical challenges are rather relevant.

For the project MAPT, the results of the load flow and security analysis has shown considerable problems to evacuate the energy of the new HVDC interconnection through the 220 kV network that covers part of the northern network of Morocco.

To reinforce the area are planned: two new 400 kV OHL circuits (220 km) between substations DAR.CHAOUL40 and SEHOUL_400;- a new 400 kV OHL circuit (20 km) between substations DAR.CHAOUL40 and MELOUSSA400, - a new 225 kV OHL circuit (19 km) between substations MLOUS225 and TANGERI225, and a new 600 MVA 400kV / 225kV transformer to be installed in the substation of ESSAHOUIRA22 along with the upgrade of the two existing ones from 450 MVA to 600 MVA.

To solve problems of flows to the substation of Tavira, the Portuguese system, the existing 150 kV and 400 kV OHL connecting the substations Ferreira do Alentejo – Ourique – Tavira (122 km) are planned to be upgraded to double circuit as well as the existing 400 kV OHL interconnection between the substation Tavira in Portugal and the substation Puebla de Guzmán in Spain (34 km).

Network analysis of the Spanish system with and without the MAPT project (differential analysis) has revealed that, apart from the installation of the second circuit for the existing 400 kV OHL interconnection between the substations Tavira in Portugal and Puebla de Guzmán in Spain (34 km), the Spanish system needs reconductoring interventions in the 220 kV network to solve the overloads greater than 15%, namely, the 220 kV OHL between the substations Almaraz – Trujillo – Mérida (60 km), the 220 kV OHL between the substations Alvarado – Balboa (60 km), and the 220 kV OHL between the substations Gillena – Centenario (39 km) in the region of Seville. Based also on the differential analysis and the MVA.km method, the previous evaluations of concrete reinforcements for overload increases higher than 15% has been complemented with a different methodology proposed by REE to cover the overload increases between 5% and 15%, which implies also that overload increases lower than 5% are neglected. These additional reinforcements are equivalent to the cost of 14970 MVA*km of 220kV lines and 131.121 MVA*km of 400kV lines. No overloads associated to the new HVDC interconnection have been identified in the Algerian system, thus no reinforcements were defined for Algeria.

For the project MAES, the results of the load flow and security analysis have shown considerable problems to evacuate the energy of the new HVAC interconnection through the 220 kV network that covers part of the northern network of Morocco.

To reinforce the area, two new 400 kV OHL circuits (220 km) are planned between substations DAR.CHAOUL40 and SEHOUL_400, a new 400 kV OHL circuit (20 km) is planned between substations DAR.CHAOUL40 and MELOUSSA400, a new 225 kV OHL circuit (19 km) is planned between substations MLOUS225 and TANGERI225, and a new 600 MVA 400kV / 225kV transformer is planned to be installed in the substation of ESSAHOUIRA22 along with the upgrade of the two existing ones from 450 MVA to 600 MVA.

The Portuguese system has not presented criticalities to sustain the energy flows in the new HVAC interconnection in the simulations. The same simulations have shown a high number of overloads in the Spanish system. Most of such overloads are caused by the high solar power generation in 2030.

Based on the differential analysis with and without the MAES project, ad hoc reinforcements have been identified to solve the overloads greater than 15%, namely, two new 400 kV substations in Guadaira and Aznalcoyar, the installation of two new 600 MVA transformers in the substation Cartuja, a new 400 kV double circuit OHL (90 km) connecting substations Cartuja – Puerto de la Cruz, a new 400 kV double circuit OHL (20 km) between substations Don Rodrigo – Guadaira, a new 400 kV double circuit OHL (10 km) between substations Tarifa – Puerto de la Cruz, a new 400 kV single circuit OHL (45 km) between substations Guadaira – Aznalcoyar, a new 400 kV single circuit OHL (20 km) between substations Aznalcoyar – Guillena, a new 220 kV double circuit OHL (33 km) between substations Facinas – Parralejo and a new 220 kV double circuit OHL (16 km) between substations Facinas – Puerto de la Cruz.

A differential analysis has shown that the Spanish system needs additional upgrading in the 220 kV network. Therefore, it is necessary to upgrade the rate of the existing 220 kV OHL between substations Tujillo – Merida (76 km), the 220 kV OHL between substations Quintos – Virgen del Rocío – Centenario – Sevilla (16 km), the 220 kV OHL between substations Alarcos – Manzanares (58 km), the 220 kV OHL between substations Los Ramos – Los Montes (12 km), the 220 kV OHL between substations Dos Hermanas – Mirabal (70 km), and the 220 kV OHL between the substations Cartuja – Don Rodrigo (89 km).

Based also on the differential analysis and the MVA.km method, the previous evaluations of concrete reinforcements for overload increases higher than 15% has been complemented with a different methodology proposed by REE 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 220 kV lines and 115.498 MVA*km in 400 kV lines. No overloads associated to the new HVAC interconnection have been identified in the Algerian system, thus no reinforcements were defined for Algeria.

For the project DZES, the outcome of the load flow and security analysis has shown no problems to evacuate the energy of the new interconnection in Morocco. The Portuguese system is (also in the context of this project) not affected by the new HVDC link. The simulation of the Spanish system has revealed a remarkably high number overloads similar to those recorded in the MAES project.

Like in the MAES project, most of the overloads are caused by the expected solar power generation in 2030. Based on the differential analysis, ad hoc reinforcements have been identified, namely, the upgrade of the rate of the 220 kV OHL (99 km) between the substations Atarfe – Mazuelos – Olivares and the installation of the second circuit in the 400 kV OHL (38 km) between the substations Tabernas – Litoral de Almeria.

In addition, this analysis has shown that the Spanish system needs additional upgrading in the 220 kV network and 400 kV network. Regarding the 220 kV network, it is necessary to install a double circuit between substations Guadame – Olivares (54 km), to install a double circuit between substations Campoamor – San Miguel de Salinas (14 km) and to upgrade the rate of the 220 kV lines in the axis connecting substations Palmeral – San Pedro de Pinatar. Regarding the 400 kV network, it is necessary to upgrade to double circuit the existing 400 kV line (79 km) between substations Asomada – Carril, to upgrade the rate of the existing 400 kV lines in the axis Benejama – Sax – Rocamora – Campoamor – Palmar, to upgrade the rate of the existing 400 kV line between substations La Plana – Guassa (40 km) and to upgrade the rate of the existing 400 kV line between substations Omledilla – Minglanilla (47 km).

Again, to complement the previous evaluations of ad hoc reinforcements for overload increases higher than 15%, REE proposed a 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 63.443 MVA*km in 220 kV lines and 423.921 MVA*km in 400 kV lines. Finally, the security analysis showed that Algerian system needs to upgrade to double circuit the existing 400kV line (240 km) between Naama 400 kV and Tlemcen Sud substations. To connect the new HVDC link to the Algerian grid it is necessary two 400kV OHL of 50km between a substation in Terga area and the substation Ain Fatah.

It is worth to mention that the differential analysis with and without the Western Corridor projects shows that in scenarios where the RES penetration exceeds a certain threshold (20 – 25 GW) in Spain and is concentrated in certain areas, the overloads start to spread in large areas of the Spanish grid. This is an important indication for the future MMPs. In fact, when a system tends to reach up to 70% of distributed generation, the planning process becomes critical since small overloads can appear on hundreds of lines. This reflects on the conventional methods of security analysis and reinforcement assessment. Those methods consider the network as the only measure to avoid overloads. In line with the worldwide debates, the support of storage, demand side management, dynamic thermal line rating, etc., should be considered in a deeper analysis and as a complement of the grid expansion. These analyses are beyond the scope of this edition of the MMP and Med-TSO suggests monitoring the evolution of the penetration of RES over the next years.

Finally, the security analysis carried out for the three Western Corridor projects highlighted that the existing AC interconnection between Morocco and Spain becomes considerably overloaded in the case of an outage of one 1000 MW nuclear generator in Algeria. 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.

4.4.2 Central Corridor

The main conclusions for the projects of the Central Corridor are summarized to the following:

For the project DZIT, results on load flow and security analysis show problems to evacuate the energy of the new interconnection through the 220 kV network that covers part of the northern network in Algeria. To reinforce the area, a new 400 kV OHL circuit is planned between Ramdane Djamel - Berrahal (65 km), plus two AIS lines bay, one in Ramdane Djamel substation and one in Berrahal substation. This reinforcement provides a new wide corridor that alleviates the 220 kV network. Concerning Italy, some overloads were not worth to consider possible reinforcements in the isle of Sardinia.

For the project TNIT, results on load flow and security analysis show no remarkable problems to evacuate the energy of the new interconnection at any of the networks involved. Therefore, no reinforcements were defined to be analyzed in this project, and it can be concluded that both the Italian and Tunisian networks have enough capability to operate with the new interconnection.

For the project TNIT2, results on load flow and security analysis show that some reinforcements are needed in the Tunisian system. Between 400 kV substations of Hawaria and Mornaguia, there are two lines, each of them with double circuit configuration and almost 1000 MW of rate that can support the interconnection capacity (1200 MW) in N situations with all lines available. To solve overloads also when one of those lines are out of service, the two lines Hawaria - Mornaguia should beupgraded to a triple circuit configuration.

In addition, a new 400 kV circuit between Mornaguia and Ouslatia (140 km) and corresponding 400/220 kV transformers at the Ouslatia substation have been also considered as reinforcements for the Tunisian network. In the case of the Italian system, no remarkable problems to evacuate the energy of the new interconnection.

For the project DZTN, no remarkable overloads associated to the new interconnection were identified in the Algerian system, thus no reinforcements were defined for Algeria. Tunisia has been the only system that has set reinforcements to be considered. To alleviate the 220 kV network, the 220 kV interconnection between Algeria and Tunisia is opened, thus the energy tends to flow through the 400 kV subnetwork. To reinforce the 400 kV network, new 400 kV circuit between Oueslatia and Mornagui substations and new 220/400 kV transformer at Oueslatia substation are considered as reinforcements. In addition, another reinforcement is needed to evacuate the power at Jendouba substation. Two different alternatives have been considered, 1) a new 400 kV circuit between Jendouba and Oueslatia substations, or 2) a new 400 kV circuit between Jendouba and Mornaguia substations. Both alternatives provide a new 400 kV corridor for the energy of the interconnection, and results obtained in the security analysis are quite similar, solving most of the overloads due to the new interconnection. Comparing them, first alternative (400 kV Jendouba - Oueslatia) seems to be a bit more effective, since the second alternative (400 kV Jendouba - Mornagui) is not capable of solving some of the problems in the N-1 situations, such as 220 kV Jendouba – Kef (PiT 4), or 200 kV B.M.Cher – Mornagui, Mnihla – Chotrana and Naassen - Mornagui .

Finally, for the project TNLYEY, results on load flow and security analysis show that some reinforcements are needed in the Tunisian system. At the Bouchema substation, the energy of the new 400 kV interconnection is redirected through the 220 kV subnetwork, leading some overloads that need to be solved. To overcome this, it is planned to include a new 400 kV corridor through Bouchema, Oueslatia and Mornaguia substations, plus new 200/400 transformers at Oueslatia and Mornaguia substations. This new corridor will be loaded by the exchanges between the north and the south and will unload the 220 kV subnetwork. Concerning the Libyan network, relevant overloads detected at the 220 kV network are detected in the network analysis It follows that all overloaded 220 kV are planned to be upgraded by reconductoring with kind of cords already adopted in the Libyan system.

4.4.3 Eastern Corridor Revised by:EB and AA

The main conclusions for the projects of the Eastern Corridor are summarized to the following:

For the project GRTRBG, most of the overloads detected identified in the Turkish system were not considered as relevant to the project. Reinforcement identified in Turkish system is the connection of the spare circuit of the Verbena (Hamitabat) – Habibler OHL as Hamitabat – Alibeykoy OHL. Verbena (Hamitabat) – Habibler OHL is being constructed as 400kV double circuit 160km OHL and spare circuit could be operated as Hamitabat – Alibeykoy OHL to reinforce the region. Also the replacement of the existing 400kV 2bundle Hamitabat – Babaeski OHL (25km) with 3bundle conductors is required to reinforce. For the Greek system two internal reinforcements were identified close to the border with Bulgaria and Turkey, consisting in the construction of two double 400kV OHL of a total length of 165km. Nevertheless, if the analysis performed had considered the foreseen increase in the NTCs with the systems of Bulgaria and Turkey as a limiting factor affecting the need for internal reinforcements, those reinforcements would not be identified. Thus, as a general remark it should be stressed that the proposed internal reinforcements are required only in case the NTCs increase exceeds the foreseen values. For the Bulgarian system no internal reinforcements have been identified. Most of the overloads can be attributed to the lack of representation of the rest of the Balkan System in the model, particularly of the system of FYROM, resulting in not realistic flows and overloads in the Bulgarian system in certain PiTs representing extreme cases.

For the project GRCYIS, minor overloads observed in the system of Greece are not considered critical and can be resolved by generation redispatch, while for the system of Cyprus, taking into account the reinforcements foreseen in the Ten Year Network Development Plan 2018-2027, no overloads were observed. Thus no internal reinforcements were identified as relevant for the project.

For the project for the project TREY the connection of planned 400kV Kozan – Sanko OHL should be modified by connecting this OHL to Misis OSB substation. After modification process, Kozan – Sanko OHL would be operated as 400kV Kozan – Misis OSB OHL and 400kV Misis OSB – Sanko OHL. This would require the construction of only 25 km of new OHL. Additionally, the replacement of existing 400kV 2bundle OHLs of a total length of 150km with 3bundle conductors is required to reinforce the region.

For the project TRIS, internal reinforcements identified in the system of Turkey consist in the construction of a new line of 80km and also the replacement of 4km of existing 400kV 2bundle OHL with 3-bundle Cardinal and Pheasant OHLs.

For the projects EYJO and JOSYTR in the Jordanian system one internal reinforcement was identified, consisting in the doubling of an existing double 400kV OHL of a length of 150 km and also the reconfiguration of two substation (Aquaba and Maan) , while an internal reinforcement was identified also in the Egyptian system, consisting in the doubling of an existing 500 kV single line of a length of 18 km and one transformer plus a new 12 km submarine cable 400kV for interconnection

For the project JOSYTR, internal reinforcements identified in the system of Turkey consist in the replacement of existing 2bundle Cardinal 400kV lines of a total length of 61km with 3bundle Cardinal or Pheasant OHL, while for the Syrian network, a new reinforcement is identified, consisting in doubling an existing 400 kV double circuit of a length of 60km.

As a general remark internal reinforcements associated with the 6 projects of the Eastern Corridor are rather shallow (close to the border analyzed), representing a small yet not negligible (in general varying from 0 to less than 30%) part of the investment cost.

Concerning losses, in general all projects of the Eastern corridor result in an increase of the overall losses, which is even more significant in the cases of the HVDC interconnections, with the exception of the GRTRBG project which results in a significant reduction of the internal losses in Bulgaria and Turkey (and a small increase in Greece) and a consequently decrease of the overall losses for the project.

4.4.4 Link with the TYNDP 2016

The Mediterranean Master Plan of Electricity Interconnections is one of the outcomes of the Mediterranean Project. It shows the result of the intense cooperation and complex coordination of the activity amongst Med-TSO Members.

The Mediterranean Master Plan is a long term HV Electricity Network Development Plan with the time horizon 2030, based on a set of common coordinated planning methodology and procedures. It builds on a number of realistic reference energy scenarios, analysed through market and grid models and studies. It identifies the main system development needs all over the Mediterranean, assessed through a sub-regional approach.

MMP 2030 defines and assesses, following a cost-benefit analysis (CBA) methodology: several potential development projects, according to the reference interconnection capacities, and the future reference grid, according to the market studies results.

These are few examples of similarities with the ENTSO-E TYNDP 2016. The Market Model has been completed to include all non-Med-TSO European countries in coherency with TYNDP 2016. However, every Med-TSO country border has a defined Bilateral Transfer Capacity (BTC) with interconnected neighbouring countries that contribute to guarantee the security of the electricity supply and allows economic exchanges of electricity. Med-TSO BTCs for the year 2030 have been directly addressed by non-European Members, while TYNDP 2016 public data have been used for ENTSO-E countries.

The costs of the projects (with their relevant grid reinforcements needed to guarantee harmonized security) are considered for applying a Cost-Benefit Analysis (CBA), whose methodology is derived by the methodology elaborated at European level by ENTSO-E. Another link with the TYNDP 2016 is the concept of Reference Grid which finds a visual representation in a map developed in cooperation with ENTSO-E, showing the current 400 and 220 kV transmission grids of the Med-TSO area.

4.4.5 The effect of the MMP 2030 on the Transfer Capabilities

Based on the assessment and following the CBA methodology, the MMP 2030 shows a substantial increase on the reference interconnection capacities, and the future reference grid, in line with the results of the market studies and network studies performed by Med-TSO.

4.5 Worth of the Master Plan

The Mediterranean Master Plan plays a key role for consolidating a secure and sustainable electricity infrastructure through the development of interconnections, while facilitating the integration of Renewable Energy Sources (RES) in the Mediterranean Region. Fourteen interconnection projects have been identified and assessed (9 of them supposed to be deployed in HVDC technology), according to the different energy scenarios elaborated at the year horizon 2030 (target year). Five of these projects link countries never interconnected before and, in addition, one of the outcomes is the end of the electrical isolation of Cyprus.

In concrete terms, the Mediterranean Master Plan shows:

• almost **18 000 MW of new interconnection capacity**;

• l**imited needs of reinforcements** (2 200 km of new lines, 840 km of reconductoring and less than 40 new bays and transformers);

• about **16 000 MEUR** of additional investments.

5 Supporting Tools for Sustainability

5.1 Enduring mission of Med-TSO

Med-TSO is fully engaged with expertise and resources in continuously providing the MMP 2030 analysis and to continue its mission and cooperation in the Mediterranean Region. In order to support Med-TSO Association in a modern environment some tools for maintaining and increasing the sustainability are needed.

5.2 DBMED

5.2.1 Task

One of the major tasks of Med-TSO is to determine the main parameters which describe the structure and evolution of the Mediterranean Electricity Grid and also to design, implement and coordinate the procedure of collection, validation, registration and periodic updating of these parameters, for all the countries involved, in a Database (DBMED), with rules of access. The ultimate objective of the creation of this tool is to facilitate the exchange of information between the Med-TSO members and to be used as the main source for the purpose of Med-TSO core activities, which are the elaboration of Grid and Market Studies for the assessment of interconnection project of interests in the Mediterranean Region.

To this end, DBMED will be used as a structured repository for storing, country by country, historical data on adequacy and related parameters like generation, NTC values, demand evolution, other statistics, but also complete information on the transmission Systems components in the form of full grid models, provided, validated and updated on a regular basis by Med-TSO members. A key feature, rendering DBMED a unique exchange tool between Med-TSO members, is the possibility to collaborate with all the different commercial software for network analysis used by the TSOs, thus enabling exchange of data and information in a more flexible, accurate, quick and effective manner.

5.2.2 DBMED Architecture

As detailed in [41], DBMED is developed as a web-based database with a dedicated server for storing and exchanging of data. It operates on a multi-user platform, considering possible different authorization levels and ensuring safe access to DBMED information stored and exchanged by the Med-TSO members.

DBMED access and use is independent of the software used by the Med-TSO members: import and export of data and network models is possible in the different software formats used by the TSOs as mentioned below:

- SPIRA (TERNA, SONELGAZ)
- CGMES (RTE, ENTSO-E data collection for Grid Studies)
- PSS-E (IPTO, TEIAS, OST, SONELGAZ, NEPCO, GECOL, ONEE, REN, REE, STEG)
- DIGSILENT (Cyprus TSO, NEPCO)
- MsExcel (general format)

Since the users of the application are located in different countries, a web application based on a three-tier architecture was adopted for DBMED, where presentation, application processing, and data management functions are physically separated. Three-tier architecture is composed of a presentation tier (web client), a domain logic tier (application server), and a data storage tier (data server). The solution requires that the users are provided with Internet access.

The DBMED implementation was developed with Extjs framework and Java for the frontend application, while for the backend database Oracle is used, a worldwide leader in database application, with highest performance, scalability and encryption options. The DBMED application runs on Tomcat webserver. For the infrastructure solution, cloud Iaas is used with the application being installed on virtualized hardware maintained by the cloud provider. Using the computer and a browser, DBMED user connects via Internet with the application. The application provides secure access by requiring user authentication, using traffic encryption (https protocols) and digital certificate to ensure the security and reliability of the connection.

Different user categories with different credentials and roles are defined within the DBMED and assigned to the TSO users, enabling them to access and manage data, as follows:

- **Administrative Controller:** manages all users (externals included) and TSO Administrators. He is the TSO Administrator of the TSOs merged networks and manages also all external TSO data.
- **TSO administrators:** manage through the Administrative Controller authorization for users of the specific TSO, upload, manage and export data of the specific TSO, can view all the information of all TSOs and also access and download TSO shared data.
- **Viewer:** can view all the information of the TSOs and download TSO shared data.
- **Guest:** external to Med-TSO association, able to view only specific aggregated information, based on the authorization provided by Administrative Controller.

5.2.3 DBMED Structure, Activities and Features

DBMED is organized into three sections [42]:

a) **Network:** network data for load flow analysis
b) **Market:** data necessary for market studies
c) **Adequacy:** historical and statistical data, for adequacy studies and reporting purposes

As described in the User's Manual [44], the connection with DBMED application includes a login with username and password to grant access to the application interface and, based on user credentials, to the main activities and features of DBMED, as described below and presented in the following figures:

Upload and Import Processes: the TSO Administrator selects a model of his network on his local PC, in one of the software formats mentioned above and additional information such as geographic coordinates, load-flow results, etc., uploads it as a zip file on the application interface and then transfers the files content into the DBMED. He can also choose to associate his import with a certain case (Year, Summer/Winter Peak, Scenario etc.) among the ones defined by the Administrative Controller. At this stage the network is visible only to the TSO Administrator that uploaded it.

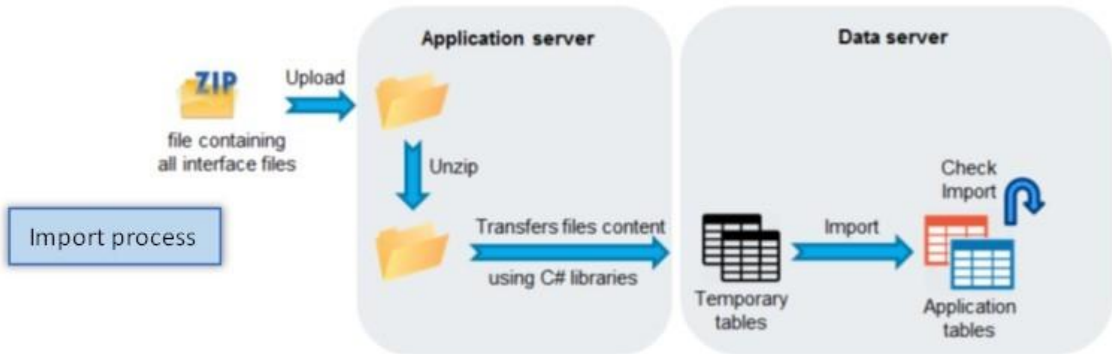


Figure 14. Upload and Import process.

Manage Process (Private Phase): at the end of a successful import process, data remain at the private phase, where it can only be accessed by the TSO Administrators that uploaded it, who can view, edit and modify some network information and also validate the export of the network in other formats to make it available to other users.

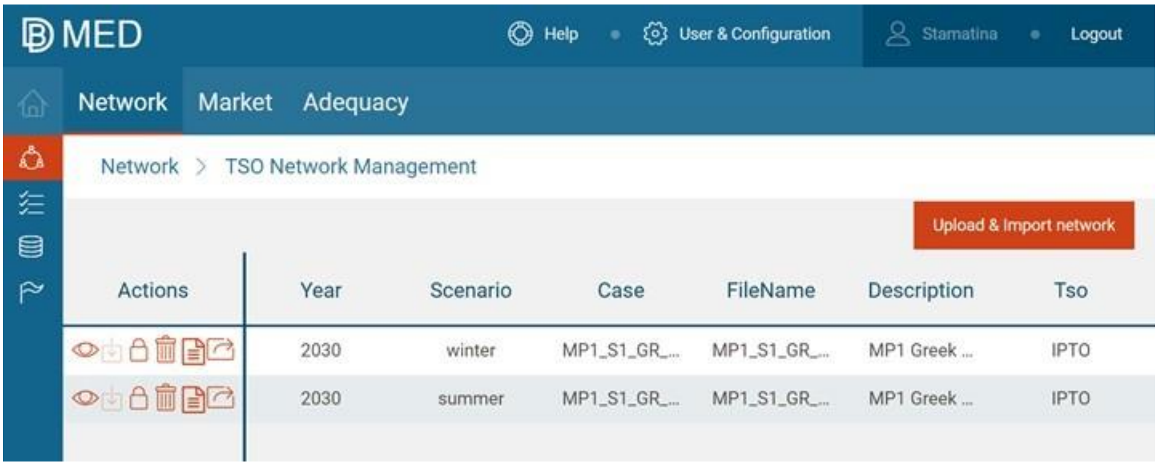


Figure 15: View of network models at Private Phase.

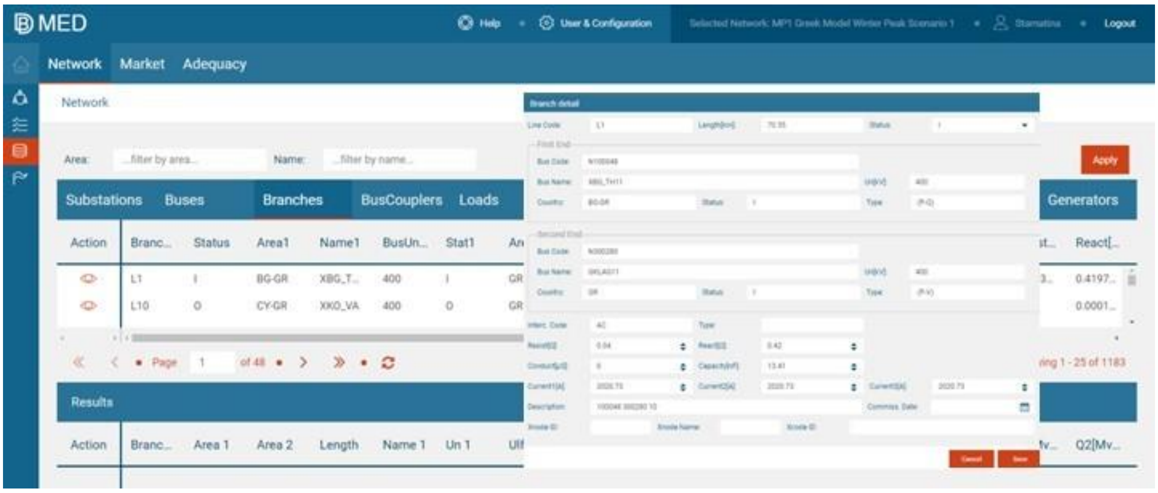


Figure 16. Data management at Private Phase.

Data management can be done within the DBMED during the private phase as mentioned above, using tables and forms. Tabular format is divided into two sections: network data and load flow results, the latter only available if results are present in the source file or provided as additional information by the TSO Administrator. Data is stored in the DBMED in multiple tables each one containing information about a type of network element (substations, busses, lines, breakers, loads, shunts, transformers and generators). An item selected in the tabular view can be opened in a more detailed from, providing more complete and exhaustive descriptions of the fields and a more structured presentation, which is also editable if authorized by user's credentials.

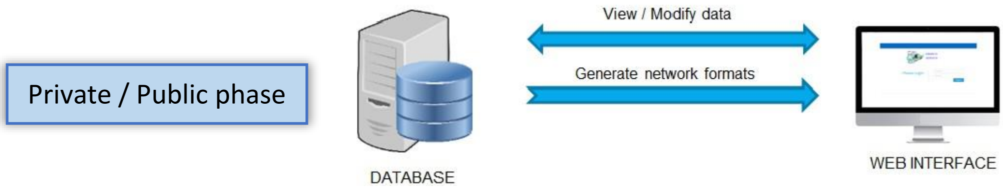


Figure 17. Data management and web interface (Private / Public Phase).

Export and Download Process (Public Phase): after previous steps the TSO Administrator can decide to export his network in all available formats before making it available (public) within DBMED to other users. Based on their credentials, authorized users can use the web interface to view public network information of other TSOs and download networks models exported in the format used by their software on their local PC. Transition between "Public" and “Private” states is possible within DBMED, but modifications by TSO Administrators are foreseen only during "Private" state, to prevent downloading networks under modification.

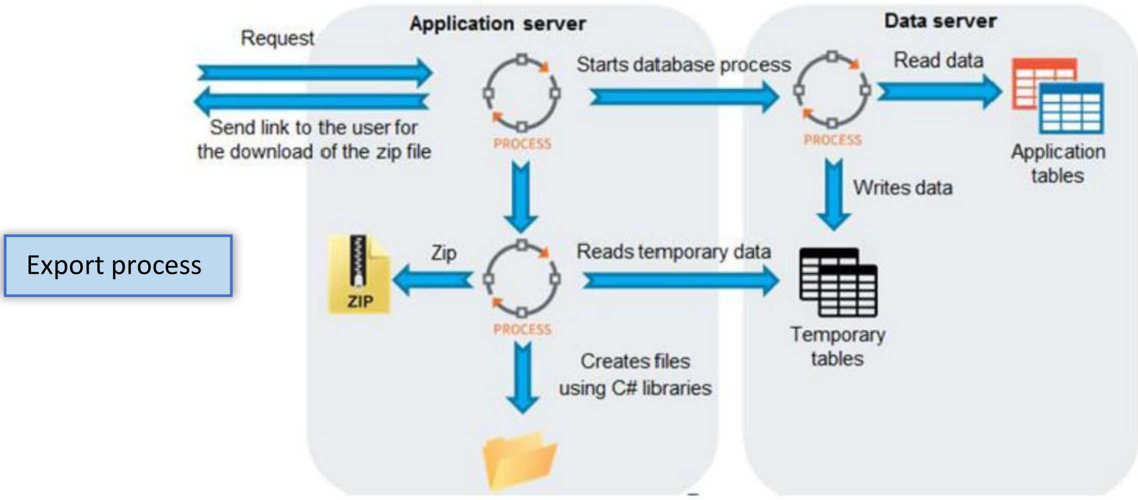
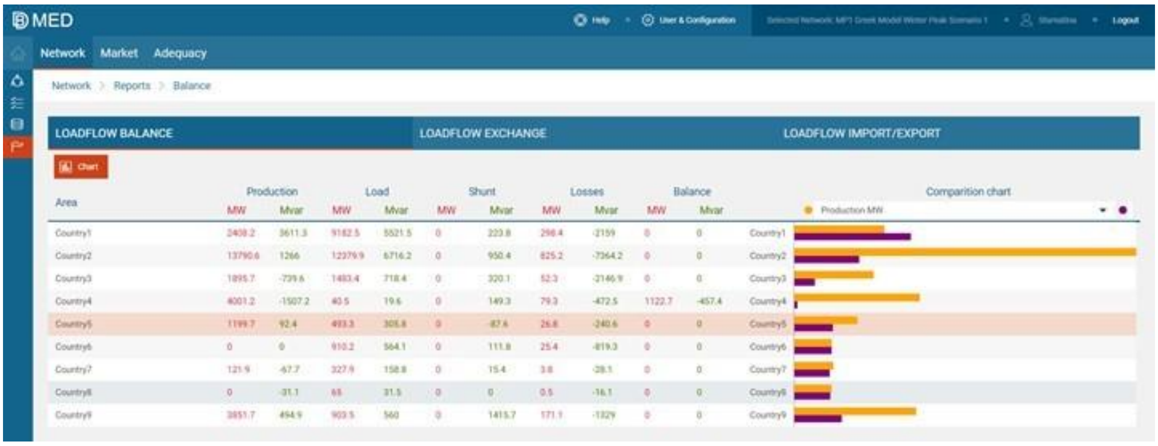


Fig. 18. Export and Download Process (Public Phase).

Reporting: a complete network with all information uploaded in DBMED, in public state and associated to a certain case as mentioned above, can supply reports with aggregated system information and exchanges with other TSOs or geographic areas.



Area	Production MW	Production Mvar	Load MW	Load Mvar	Shunt MW	Shunt Mvar	Losses MW	Losses Mvar	Balance MW	Balance Mvar
Country1	2408.2	3611.3	9182.5	5521.5	0	223.8	298.4	-2159	0	0
Country2	13790.6	1266	12379.9	6716.2	0	950.4	825.2	-7364.2	0	0
Country3	1895.7	-739.6	1483.4	718.4	0	320.1	52.3	-2146.9	0	0
Country4	4001.2	-1507.2	40.5	19.6	0	149.3	79.3	-472.5	1122.7	-457.4
Country5	1199.7	92.4	493.3	305.8	0	-87.6	26.8	-240.6	0	0
Country6	0	0	910.2	564.1	0	111.8	25.4	-819.3	0	0
Country7	121.9	-67.7	327.9	158.8	0	15.4	3.8	-28.1	0	0
Country8	0	-31.1	65	31.5	0	0	0.5	-16.1	0	0
Country9	3851.7	494.9	903.5	560	0	1415.7	171.1	-1329	0	0

Figure 19. Report and Graph on Load flow balance.

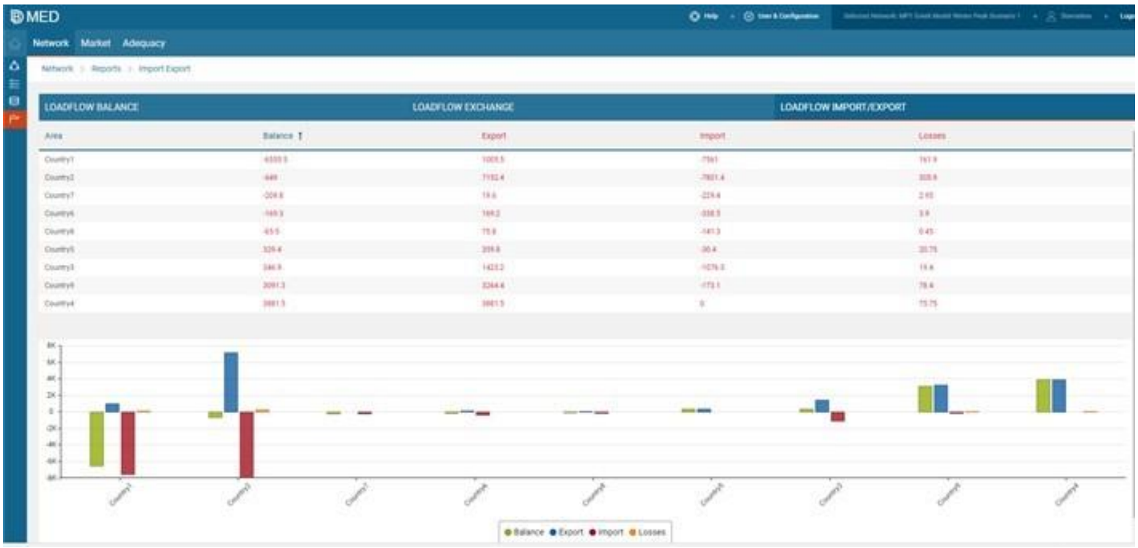


Figure 20. Report and Graph on Import/Export.

Confidentiality considerations, according to current sharing polices foreseen in the Med-TSO Internal Regulations (Article 24), are taken into account within DBMED. Thus all TSO Administrators have full access to data and information uploaded in the DMBED, while other Users have access limited according to their credentials. It is foreseen that Users are informed by the DBMED on the sharing policies every time a network model is made public, but also when a User attempts to downloads a network model. Future changes in sharing policies are managed centrally by the Administrative Controller.

5.3 The Grid Map

This map is a comprehensive illustration of the transmission system network operated by members of the Association of the Mediterranean Transmission System Operators, and it has been developed in cooperation with the European Network of Transmission System Operators (ENTSO-E).

The map represents some 400 000 km of high voltage lines in the Med-TSO region as per the end of year 2016, and it is the first of its genre to give a comprehensive picture of the status of the electric interconnections within the Mediterranean region, an area that groups three different synchronous zones:

- ENTSO-E's synchronous Continental Europe zone,
- South Western Mediterranean Block, which is synchronous with the ENTSO-E's synchronous Continental Europe zone;
- South Eastern Mediterranean Block

The lines represented, constitute the relevant electricity grid, i.e. the portion of the grid that can affect the interconnections between the power systems.

In general, the map depicts all transmission lines designed for 220kV voltage and higher and generation stations with net generation capacity of more than 100MW. It is important to note that the map takes into account also the lines between 110 and 150kV given the peculiarities of the power systems of the members of Med-TSO. Moreover, the map includes five zooms in order to highlight the existing interconnections within the Mena region.

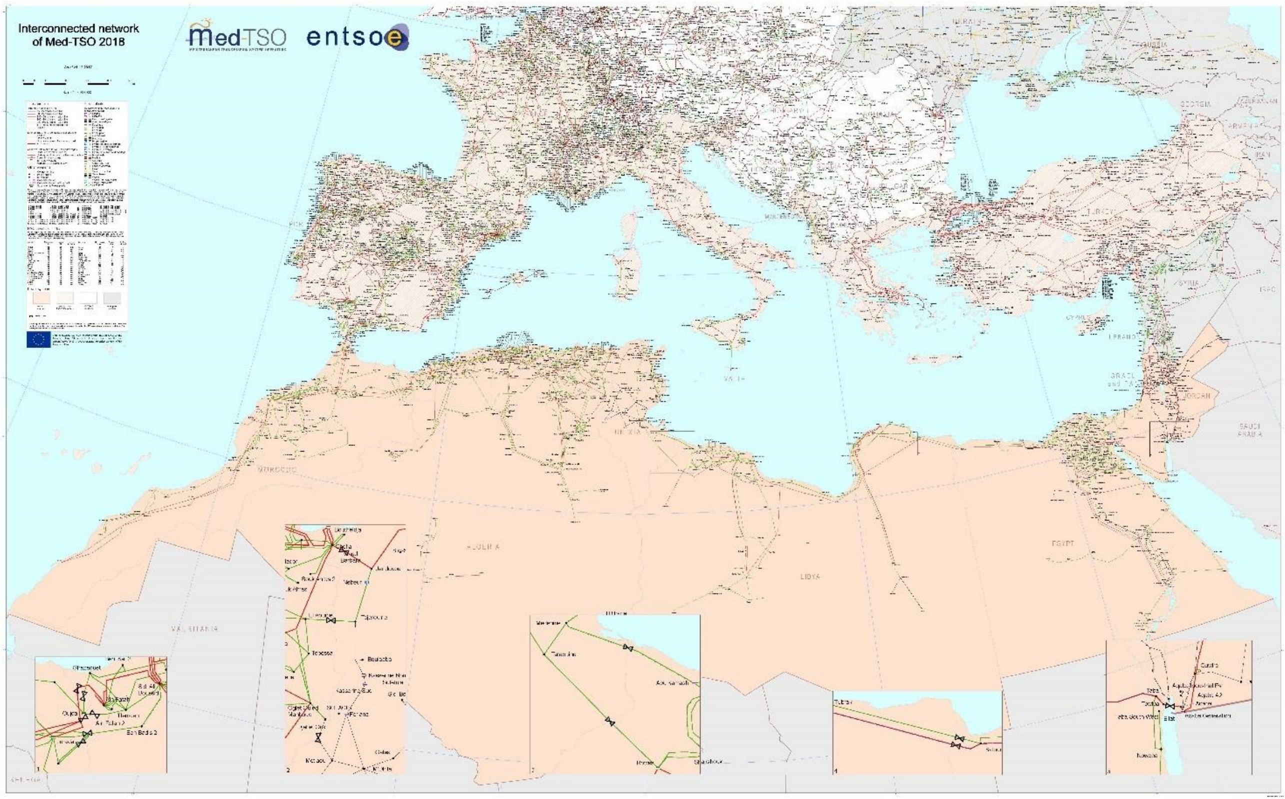


Figure 21. Interconnected Network of Med-TSO Map.

6 Future Master Plans

6.1 A periodical process

MMP 2030 is the result of about 3 years of complementary activities, initially addressing the design and consolidation of the grid planning methodology harmonized (and where applicable compliant) with the ENTSO-E practices. This has been complemented in the second phase by the application of the agreed methodology and the data acquisition to consequently perform the market and grid analyses. The third phase has been dedicated to the analyses (market and network) allowing the careful consideration of the 14 projects. This process is expected to be repeated biannually by the Med-TSO Members. This periodic update of the MMP 2030 will be based on full alignment with the NDPs and closer coordination with ENTSO-E.

6.2 Next steps

Med-TSO association has successfully performed the “Mediterranean Project I” co-financed by the European Commission, aiming at supporting the assessment of infrastructure projects in the Mediterranean Region, organized according to five main streams of activities: rules, infrastructure, International Electricity Exchanges, Knowledge Network and Med-TSO Database.

Furthermore, Med-TSO is fully committed to continue the consolidation of a more Secure and Sustainable Electricity Infrastructure in the Mediterranean Region with a focus on increasing the interconnection capacity in the region. This new Action called “Mediterranean Project II” is developed in the frame of the initiatives aimed at reducing the cost and the environmental footprint of electricity in the Mediterranean region and in the connected neighbouring regions. All these initiatives have as beneficiaries the final customers/citizens and the planet, in the context of climate change and economical and societal development.

From the TSOs’ perspective, the overall objective of the Master Plan is to promote the progressive integration and interconnection of Power Systems and the enhancement of cross-border electricity exchanges in the Mediterranean region. In fact, this overall objective would allow to:

a) **increase energy security and reliability**;
b) **enhance RES penetration**, thus reducing the environmental impact of the electricity generation
c) **facilitate RES integration** in the Mediterranean Region, encouraging cost-effective RES exchanges both North-South and South-South;
d) **increase the overall system efficiency**;
e) **generate economies of scale in investments and operations**.

Meeting the above-mentioned objectives is a need for the Mediterranean countries, in order to face the challenges that the energy transition (with its high RES penetration) is posing to the TSOs everyday business and long-term planning activities. The Mediterranean Project II will be the context where the achieved experience of the more developed countries will be put in common with the other countries, which will be facing the same challenges in the next future.

Med-TSO’s proposal is to contribute by continuing and, where possible, consolidate and improve the activities carried out by the previous Mediterranean Project funded by the EC. Med-TSO will develop the proposed Action according to its Action Plan 2018-2020, aimed at extending and integrating the Mediterranean electricity systems, in line with the objectives of EU's Neighbourhood policy on Energy and Climate Change.

6.3 Specific objectives

The overall objective of the Action is expected to be achieved through the coordination of both national development plans, operation and rules to access the grids. Therefore, the first specific objective of this proposal is to build up on the results of the "Mediterranean Project" and continue in setting up common standards and rules and facilitating the integration of the Mediterranean Power Systems, with a special attention to cross-border sub-regional and neighbourhood-wide cooperation. The Action is also aimed at consolidating the network among Med-TSO Associates for exchanging knowledge and experiences, as well as improving the common Mediterranean database for sharing data and information to facilitate, therefore, the undertaking of regional studies.

Furthermore, Med-TSO has identified the need for strengthening the TSOs' cooperation in both system operation and system development. This is necessary, in particular, for facing the expected growth of RES, facilitated by the current decrease of their installation cost. The Mediterranean Region has been identified as one of the most sensitive regions to climate change in the world. The entry into force of the Paris Agreement at COP22 is an important signal with direct impact on the roadmaps for renewables integration, based on now-binding targets, with the new EU-wide target of a 35% clean energy share by 2030. The increased volatile flows that the TSOs need to control call for a reinforced cooperation within the interconnected power systems.

The already mentioned overall system efficiency to be gained through the integration of the transmission grids calls for additional key specific objectives to be achieved with the multilateral cooperation proposed in the Action. Assessing the use of innovative technologies in new projects and exchange of know-how can contribute to this objective, as well as defining the conditions for sharing resources (power generation), because they can determine significant cost reductions and more limited risk of investments in infrastructures. In addition, the possibility to combine and operate power systems that have complementarity of load profiles and generation mix in a more integrated way is another benefit highlighted by the Action, with direct impact on increasing the energy efficiency.

In order to support such increased cooperation, there is a strong need to address new activities for harmonizing the rules and integrating the systems, as proposed by Med-TSO in the new Master Plan 2018-2020. In continuity with the organization of the previous Mediterranean Project, Med-TSO proposes a new Action structured along the following activity streams:

1. Planning of infrastructures
2. Regulation & Power System Rules
3. Scenarios Adequacy and Market Studies
4. Grid development & Market integration
5. Operation of Power Systems
6. Training and Knowledge sharing

6.4 Key Expected Results

The key expected results of the Med-TSO proposed new Mediterranean Master Plan 2018 – 2020 are:

6.4.1 Planning of infrastructures

An integrated package of activities is developed in the frame of the Action, aimed at delivering:

- a rolling N-Year Mediterranean Network Development Plans (NYMNDP)
- a report on the status of the HV electricity interconnections around the Mediterranean and within the Southern Bank countries.

6.4.2 Regulation & Power System Rules

The relevant activities measure the progress in the harmonization of regulation in the Mediterranean region for power system rules (in the perimeter of the network codes). This includes a "zonal approach", with a program for implementing faster at least a subset of rules in some selected zones of the Mediterranean (pilot projects). Expected results are:

- a proposal on harmonization of technical rules in the fields of management and sharing of system services;
- a Zonal Target Regulatory Framework;
- a Transparency proposal on a set of data to be published by all the Med-TSO Members;

6.4.3 Scenarios Adequacy and Market Studies

The Association intends to draw some possible future scenarios for the Mediterranean Power System. To this aim, the following results are expected.

- A set of mid- and long-term scenarios of the Mediterranean Power System. The Market model is built to apply the CBA methodology for assessing interconnection transmission projects.
- A periodic Adequacy Report, including Winter or/and Summer Outlook Reports, to complement a statistical approach by severe scenarios simulations which are useful to prepare the crisis management tools.

6.4.4 Grid development & Market Integration

New complementary activities are foreseen, according to Med-TSO's Action Plan, to cover relevant aspects of the TSO's business:

- business models for investments in interconnections (taking into account also the benefits in terms of RES integration);
- grid integration in the Mediterranean and impact on climate change (increased energy efficiency as a result of electricity transmission network integration);
- allocation of costs and risks for new investments;
- assessment on regional Permitting Procedures.

6.4.5 Operation

The Action Plan expects to increase the exchange of information related to the operation of the Med-TSO Members' Power Systems. To this aim, the following features should be developed:

- a Common Web-Platform for TSOs members to gather information on cross-border interconnections;
- a periodical report on the behaviour of the regional electricity system.

6.4.6 Training and Knowledge sharing

Human Resources Management is a priority for the development of a new culture, capable to activate new development processes. To this aim, it is proposed to set up an intensive exchange of expertise, training, workshops and events for knowledge dissemination, both internal and external.

6.5 A look at the cooperation with the European Commission

The cooperation of Med-TSO with the European Commission DG NEAR and DG ENER is key for the Mediterranean Master Plan development.

The mission of the Directorate-General for Neighbourhood and Enlargement Negotiations (DG NEAR) is to take forward the EU's neighbourhood and enlargement policies, as well as coordinating relations with EEA-EFTA countries insofar as Commission policies are concerned. DG NEAR works closely with the European External Action Service and the line DGs in charge of thematic priorities, including with the Directorate-General for Energy (DG Energy).

The Directorate-General for Energy is one of 33 policy-specific departments in the European Commission. It focuses on developing and implementing the EU's energy policy – secure, sustainable, and competitive energy for Europe.

The major impact of the proposed Mediterranean Master Plan and its continuation is related to regional cooperation in the European Neighbourhood, complementing the current national assistance programmes. This will mainly address regional challenges in the electricity sector, promote cooperation amongst TSOs partners and builds bridges with direct impact on the cooperation and social stability in the Mediterranean Region. The new Mediterranean Master Plan encourages South-North and South-South cooperation and promotes dialogue, exchange of views and knowledge sharing, with direct impact on electricity market integration.

Regional cooperation usually involves all the countries in the Southern Neighbourhood, but can also take place at sub-regional level. Mediterranean Region is not homogenous; therefore the proposed sub-regional (zonal) approach may take into account properly the national diversities, promoting faster harmonisation where possible.

In terms of sustainability, one of the main outcomes of the new Mediterranean Master Plan is to define the way to facilitate market development, exchanges and RES integration through optimized and increased electricity exchanges among Med-TSO countries.

The new Mediterranean Master Plan requires multilateral cooperation, between Institutions and Companies, and a strong political will. In fact, Med-TSO's initiative is based on multilateral cooperation as instrument of integration of the Mediterranean Electricity Systems, whose benefits result from the sharing of resources (primary energy sources, power generation, and know-how), costs and risks of investments in infrastructure.

During the next ten years, the TSOs forecast an increase in the generation capacity in the Mediterranean of about 150 GW, of which 15% are expected from RES, corresponding to an expected increase in electricity demand of about 90 GW. The related investments amount to 220 - 250 billion €. This requires the HV network strengthening and integration of the two shores of the Mediterranean. The TSOs estimate the construction of about 33,000 km of HV lines, with around 20 billion € of investments.

To reach the objective and results, the TSO Members of Med-TSO will contribute to the project in terms of resources. Finally, in order to guarantee the sustainability of the actions, an efficient telecommunication system could be envisaged and provided to the members to improve the effectiveness of participation.

7 Reference Documents (Bibliography)

	Type(*)	Title	(Issued by) Issue date
	N	Task 2.1.2 – Mediterranean Master Plan of interconnections- Objective 2030 – Outlook of the Tasks and deliveramle	This document
[1]	D	Deliverable 2.1.2 - The Grid Planning Methodology 01_Planning_Metodology_v. 1 .pdf	(MedTSO) 25/05/2016
[2]	D	Deliverable 2.1.2 - Guidelines for the coordinated Planning in Med-TSO Area- Survey and tools for supporting the harmonized Planning Process 02_Fesibility_Survey v.1.pdf	MedTSO 25/05/2016
[3]	D	Deliverable 2.1.2 - Procedures for the Mediterranean Master Plan 03_Procedures v.1. pdf	(MedTSO) 25/05/2016
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[5]	D	Deliverable 2.2.1 – Description of the reference energy scenarios	(MedTSO)07/08/2017
[6]	D	Deliverable 2.2.2 Euro-Mediterranean Market Model for evaluation of the impact of basic scenarios and expected energy flows on the Euro-Mediterranean Electricity Grid. Analysis of the complementarities around the Mediterranean Power System and within sub-regional groupings,	(Med-TSO)18/o5/ 2018
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[8]	D	Task 3.3 of committee TC03 Analysis and application of CBA methodology - criteria and assessment for interconnections cases studies.	(Med-TSO) 21/01/2018
[9]	E	Med-TSO Regional Market Study – Final Report (ROUND A)	(Med-TSO &CESI)
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28	D	Snapshot Building Process	
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[**34**]	B	Paving the way for the Mediterranean Solar Plan-Task C – Deliverable 1- National Development Plans	(Med-TSO)July 2013
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(*) D= DELIVERABLE. N= Note, not in the deliverables. B= Med-TSO document. E= external document.