Deliverable 2.1.1

Guidelines for Coordinated Planning:

b) Survey and Tools for supporting the Harmonized Planning Process

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"Mediterranean Project"

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

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Table of contents:

General Introduction

Survey and Tools for Supporting the harmonized Planning process.

General Introduction

This section is dedicated to the survey that TC2 performed in 2015 to assess the differences in approaching market and technical issues. The section includes the orientation of TC1 as far as tools are concerned.

1.1 Planning Criteria

Med-TSO considered important the assessment of the planning criteria that each TSO member adopts for three main reasons: a) to assess the present level of compatibility among systems b) to guess the time needed to design tools and guided procedures and develop a common technical approach, c) to guarantee transparency in the quantitative evaluations and for the further operation.

1.1.1 Technical criteria

To this purpose a survey on the planning criteria has been carried out. Most of the Members contributed with most valuable information. The enquiry concentrated on technical issues (network performances).

12 members of Med-TSO out of 18 have responded and provided information about Main Planning Criteria considered in their systems on the base of a questionnaire set up by TC1.

The outcome of the survey shows that most of the countries have similar criteria, with limited exceptions in some cases, due to network specificities of each country. Some differences are also possible to find when comparing the countries belonging only to Med-TSO Association with those belonging to the Med-TSO and ENTSO-E as well. All Countries adopt procedures inspired to the best practice.

However, it is possible to conclude that all TSOs consider:

- Long-Term period (Ten Year Network period or more in some cases);
- Steady state security analysis (load-flow calculation) taking into account:
  - Thermal limits (normal and overload for lines and transformers)
  - Voltage limits
  - N-1 contingencies analysis (some TSOs consider N-2 contingencies or more severe contingencies in particular cases of network),
- Voltage collapse analysis,
- Short-circuit calculation, and
- Transient stability studies

To perform the studies referred above, all transmission systems in Med-TSO have defined the operation limits, like overloads, voltages and angular difference acceptability limits. These limits are defined to normal conditions and under contingency conditions.

In other words the harmonization work should be concentrated on refining the voltage and frequency acceptable limits and the loadalbility of the network elements.

Definition of rules, in cooperation with TC2 and TC3 is recommended concerning:

- The interpretation of N-1 security rules (preventive/curative) and the remedial actions to countermeasure the contingencies
- The calculation methods of NTC

Detailed outcome of the survey is reported in Appendix 2.

1.1.2 Market related criteria

No tools for market studies have been detected in the Southern bank TSOs

The Northern bank TSOs are supposed to run evaluations on the base of the ENTSOE Requirements. Concerning market studies indirect conclusion can be taken from the parallel survey on tools.

1.2 Existing planning tools assessment

1.2.1 Objectives:

To elaborate studies for Mediterranean electrical systems for a fully integrated system or for sub regional systems, it is necessary to use a common computing tool or tools of the same level in order to have comparable results. In this aim it has been necessary to:

1. Identify the calculation tools used for the development of electricity transmission networks.
2. Present the characteristics of each tool: database (format and parameters), modelling, solving methods, outputs results ... etc.

Moreover, it has been envisaged to analyze:

- How to make any computation SW compatible with the data;
- How to set up a standard package of common tools;
- How to make the tools compatible with ENTSO-E data.

This analysis has been used to take a no regret decision about data base features and interfaces.

1.2.2 Working approach:

In view of performing activities listed above, a questionnaire on planning tools has been developed and was filled by TSO, after collecting information requested a summary report is prepared with a list of different tools used by TSO (see chapter 8).Results:

This section gives a summary report of the questionnaire on electrical network tools and it provides an overall synthesis about electrical systems tools calculation used by the TSO Members of Med-TSO.

The conclusions on tools are based on the answers from 13 TSOs. The sample is considered sufficient for the purpose for consolidating some technical choices.[1]

The analysis of information covered by the survey indicates that there are three categories of calculation tools as following:

1. **Networks analysis tools:** load-flow, short-circuit calculation, stability analysis...etc
2. **Probabilistic analysis tools:** adequacy and reliability studies.
3. **Market studies tools.**

For the first category "network analysis", the following packages are used:

- **PSS/E** used by 9 TSO.
- **SPIRA** used by 2 TSO(Sonelgaz and TERNA)
- **DigSILENT** used by Cyprus
- **CONVERGENCE** used by RTE.

The only main common tool used by the Member TSOs is PSS/E (9 out of 13 Members).
SPIRA is used by two Members, Sonelgaz from Algeria and Terna from Italy. ONEE from Morocco, REN from Portugal and IPTO from Greece use EMTP addition to PSS/E and NEPCO from Jordan uses DIgSILENT in addition to PSS/E.

For the other two categories of tools (Probabilistic and market studies tools) only RTE (France), IPTO (Greece), REN (Portugal) and REE (Spain) and Terna (Italy) adopt market tools which are not of the same type.

The survey shows that the Network Analysis Tools are aligned to the best standards and that the Members comply with the basic practices for Network Calculations.
All tools are reliable and largely used therefore no problems are expected in terms of quality results. That is under the same input the same results are expected using different tools.
The large diffusion has proven by experience that interfaces and data conversion in different formats are possible and manageable with reasonable effort. This guarantee the needed transparency and participation of Members in a) supplying data to be used for calculations, b) performing their calculations at block level and Country level with limited use of external equivalents, c) verifying the results performed by different TSOs.

More details on the survey are reported in the following table.

[1] Contributed to the survey: OST (Albania), SONELGAZ(Algeria), Cyprus - TSO (Cyprus), RTE (France), IPTO (Greece), TERNA(Italy), NEPCO (Jordan), GECOL (Libya), ONEE (Maroc), REN (Portugal) , REE (Spain), STEG (Tunisia), TEIAS (Turkey).

		Networks analysis			Network Probabilistic analysis	Market studies
unt	TS	Tools	Main functions	Data Base Interfaces		
Albani	OST	PSS/E	• Load-flow, • Short-circuit • Transient stability	Text and Excel		
Algeria	SONELGA	SPIRA	• Load-flow • Short-circuit calculation	Access and Excel		
		SICRE	• Stability simulations			
Cyprus	TSO	DIgSILENT Powerfactory	• Stability (RMS), • Load Flow, • OPF	Text, Excel, Access, other		
France	RTE	CONVERGENCE	• Load-flow • Short-circuit calculation	Compatible with: UCTE/ENTSO-E, CIMV1 and CGMES ENTSO-E Import/Export from/to, easy to manage format EXCEL, XML, CSV		ANTARES
		PTDF Methodology	• Based on the market study results, this tool detects the main probable grid constrains			
		ASSESS	• This tool is used for 400kV studies. It's a statistical tool and an optimizer of the grid.			
		EUROSTAG	• Stability issues			
Greec	IPTO	PSS/E	• Load-flow, • Short-circuit • Transient stability	Text, Excel, other		In-house software

		Networks analysis			Network Probabilistic analysis	Market studies
unt	TS	Tools	Main functions	Data Base Interfaces		
		EMPT	• Load-flow • Short-circuit calculation • State and Dynamic simulations			
Italy	TERNA	SPIRA	• Load-flow • Short-circuit calculation	Excel	GRARE	PROMED
		SICRE	• Stability simulations			
Jordan	NEPCO	PSS/E	• Load-flow, • Short-circuit • Transient stability	Text and excel		
		DIGSILENT	• Load-flow • Short-circuit calculation • State and Dynamic simulations			
Libya	GECOL	PSS/E	• Load-flow, • Short-circuit • Transient stability	Text and Excel		
Morocco	ONEE	PSS/E	• Load-flow, • Short-circuit • Transient stability	Text and Excel		
		EMTP	• Load-flow • Short-circuit calculation • State and Dynamic simulations			
Portug al	REN	PSS/E	• Load-flow, • Short-circuit • Transient stability	Text and Excel or others	RESERVAS	VALORAGU A

		Networks analysis			**Network Probabilistic analysis**	**Market studies**
unt	**TS**	**Tools**	**Main functions**	**Data Base Interfaces**		
		EMTP	• Network electromagnetic transients simulation		ZANZIBAR: Only in DC	
Spain	REE	PSS/E	• Load-flow, • Short-circuit • Transient stability	Text and Excel		UPLAN
Tunisia	STEG	PSS/E	• Load-flow, • Short-circuit • Transient stability	Text and Excel		
Turkey	TEIAS	PSS/E	• Load-flow, • Short-circuit • Transient stability	Text and Excel		

1.3 Data Base

One of the main objectives of MED-TSO is to promote the cooperation, coordination and development of the Mediterranean Electricity Grid. This is achieved by sharing information on the Mediterranean Electricity Sector, which shall be collected and stored in the MED-TSO Database. Based on this information, a model for system and market studies will be built, in order to assess the projects which are under consideration in the MED-TSO development plan. In addition to these main functions, the MED-TSO Data Base shall serve as a repository of information, such as historical and statistical data, to be used for adequacy studies and for reporting purposes.
Furthermore, the MED-TSO Data Base shall provide the TSO Members with input data for quantitative analysis and evaluations, the results of which shall be stored in the Data Base.
Users of the DB are the MED-TSO Secretariat, the TCs and the WG ESS members. These entities/members are also called to contribute to the definition of the data to be supplied.

Database will include access and administration rules.

Taking into account the global energy market, the ESS WG shall build a number of different scenarios in order to simulate possible futures for the electricity market in the Mediterranean area, based on parameters such as the electricity demand expectations, the generation mix for each country, the evolution of load with respect to the economic development, as well as fuel prices and resources in the area. This information shall be collected and stored in the Market section of the MED-TSO Database. Furthermore, a complete set of the electrical parameters of the network components and the operational conditions required for performing a power flow calculation at representative years and system conditions shall be collected and stored in the Network section of the MED-TSO Database. In addition to the above, information such as historical data on adequacy, NTCs, evolution of demand, other statistics and reporting, shall be stored on a structured repository generically indicated as the Adequacy section of the Database.

The above mentioned sections compose the MED-TSO Database, which will serve as the reference for the Mediterranean system and market studies. The output of these studies shall be used in order to evaluate the impact of the projects considered in the MED-TSO development plan on the current and future electricity markets, based on the integration of the Euro-Mediterranean electricity systems. All information stored in the MED-TSO Database shall be validated and periodically updated.

The general information to be included in the MED-TSO Database is briefly described below:

1.3.1 MedTSO DATABASE Contents

Market and Scenario Evaluations

The data set of the market representation includes scenario outlook and adequacy forecast, monthly statistics data, yearly statistics and adequacy data. Appropriate level of aggregation shall be performed to certain categories of Market data which contain commercially sensitive information in order to ensure non-disclosure of confidential information or to avoid pointing to individual market parties. These data for each scenario are briefly described below:

- **Net generation capacity (clustered)** per country and fuel type for thermal generation or per technology for RES generation.
  - Efficiency, CO2 emissions, variable cost, commitment constraints, standard unavailability
  - Hydro, Time-series or detailed (weekly inflow for annual/weekly/daily reservoir) and pumping
- **Basic standard modelling features of different generation technologies,** such as:
  - assumptions on the efficiency range per type of thermal power plants
  - average capacity factors and average output range per RES technologies
  - non-usable capacity, maintenance and overhauls, outages, system service reserve
- **Prices (Fuel & CO_2 emissions):** aggregated price assumptions on fuel and CO_2 emissions prices for the Med-TSO area.
- **Transmission capacities:** assumptions on the transmission capacities between countries across the Med-TSO area.
- **Load Demand per contry (hourly)**
  - Annual load curves for each scenario
  - Historical load data
- **Country generation mix:** it includes for each scenario per country assumptions on the hourly generation per fuel type for thermal generation or per technology for RES generation.
- **Climatic data base** per country. to perform Montecarlo statistical studies.
- **Year series of hourly Wind producible energy per MW of installed capacity**
- **Year series of hourly Solar (PV) producible enegy per MW of installed capacity**
- Exchanges (with countries not included in the model
- Exchange Capacity (BTC) between modeled countries
- Value of energy not supplied

<u>Network Studies</u>

The data set of the network representation includes information on the electrical parameters of network components and operational conditions, which are briefly described below:

- **List of all system substations with voltage level higher than 220kV**
  - The level of power system representation may be expanded to transmission voltage levels lower than 220kV (such as 150 kV, 132 kV and 110 kV levels where applicable), in the case of parts of the network which are indicated by the relevant TSO as playing a significant role in local transmission tasks.
  - Branches and substations of the network under the 110 kV voltage level may not be represented in detail and relevant information could be aggregated at the closest extra-high voltage (EHV) node.

- **Generation and Demand data** in every substation node, with appropriate level of aggregation, in order to ensure non-disclosure of confidential information.
- **Branch and transformer data:** complete set of all circuits and transformers with their basic electrical parameters, such as:
  - Resistance, reactance, susceptance (R,X,B)
  - Steady state capacity (in Ampères) or rating (in MVA)
  - Transformer regulation
- **HVDC links** modelled explicitly with at least:
  - Rating (MW, MVAr)
  - Connection points (system nodes)
- Other system devices (such as fixed or switched shunts, FACTS, synchronous condensers e.t.c) should be modelled explicitly with respect to the voltage level of power system representation mentioned above.
- All above parameters for grid elements should be provided, regardless of whether or not the elements are under consideration, out of service or undergoing maintenance.

For the ENTSOE area, all the grid data will be provided to Med-TSO by ENTSOE. This mechanism, already approved by ENTSOE, is necessary to avoid TSOs sending several times the same information to different TSOs associations and ensures that all TSOs associations share the same data.

1.3.2 Network Studies Section

The Network analysis section will be derived by the SPIRA data base as long as the license will be granted by Terna.

Med-TSO will facilitate the data for the agreed network studies in the formats used by the Member TSOs, that is, PSSE, DigSILENT and CONVERGENCE.

This will allow any TSO to verify with its own network analysis tool all the agreed network studies performed with the SPIRA tool and Med-TSO to merge networks originated by PSSE DigSILENT and CONVERGENCE. Moreover, they will be able to perform its own subsequent network studies using its own tool.

1.3.3 Confidentiality

Members are committed to populate the data base with the appropriate information and level of detail, in good faith and timely as soon as required. Members of the ENTSOE area will fullfill this commitment only through ENTSOE, which will facilitate to MedTSO all the required information.

Members are bound by confidentiality and reciprocity conditions as well. Non-disclosure agreements will be signed if needed.

Confidentiality has two aspects:

1. The confidentiality obligations that each Member has to comply with, considering sensitive information belonging to third parties (Information type A)
2. The confidentiality obligations that each TSO Member has to comply with, considering sensitive information belonging to another Member (Information type B)

Regarding Type A, TSOs are allowed to supply data in aggregated form, as described in paragraph 1.1.1.

Regarding Type B, no particular constraints are envisaged, given that confidentiality shall be covered by a general inter TSO mutual non-disclosure agreement.

1.3.4 Data storage

The data will be stored in a dedicated server located at MedTSO premises. MedTSO Secretariat is responsible of the maintenance, cyber security and non-disclosure constraints.

1.3.5 Property of data

Data and information remain properties of the TSO Members.

1.4 Drivers for coordinated transmission grid planning in the Med-TSO area

Harmonizing the planning approach among Med-TSO countries represents the main challenge towards a coordinated and integrated development of transmission grid within the Mediterranean area.

In this context it is vital to bear in mind the driving elements that guide the single TSOs in setting up their national development plans. In this section by *drivers* is meant the set of prime movers that orient the objectives and the goals of a national development plan.

Being in line with the drivers of the single TSOs in the planning process helps the acceptance of the proposed solutions and the probability of its seamless success.

In general, the drivers for planning adopted by ENTSO-E countries are mostly based on market-related aspects (Increasing of Socio Economical Welfare, Integration of RES, Limits on CO_2 emissions, etc.) since almost all of those countries have already experienced the unbundling of electricity sector as well as the creation of the energy markets. Conversely, as far as the Mediterranean countries are concerned the development of the power grid is often carried by integrated utilities which have as primary drivers the improvement of Security of Supply as well as quality of the transmission service in the country.

To this purpose an enquiry has been carried out whose feedback needs further analysis. It's outcome confirms the above mentioned concept. That is in northern bank of Mediterranean sea TSOs are more driven by competition in market and much less in adequacy while the Southern bank is oriented by Security of supply linked with the growth of the demand and very little in market issues.

The two main drivers can be complementary and facilitate the integration of the two systems.

Given the above mentioned context, to favor a structured and shared approach to system planning activities- with respect to mid- and long-term horizons – a set of drivers for the development of an adequate and even more integrated and interconnected transmission system in the Med-TSO area should be adopted. Following are listed the main drivers to be considered:

- To provide a high level of security of supply for all the countries;
- To ensure a safe operation of the even more interconnected system;
- To facilitate grid access and the development of market schemes;
- To facilitate competition in order to improve the efficiency of the system;
- To promote the harmonization in the operation procedures among countries
- To contribute to a sustainable development of each Country;

The common planning procedures in the Med-TSO area should also take into account the following side-context aspect:

- national legislation and regulatory framework,
- European and Maghreb countries policies and targets,
- transparency in procedures applied

Additional drivers related to specific context/country could be considered as well.
The Mediterranean integration also requires the definition of common scenarios which provide information about the evolution of economical and geo-political context regional wide at a certain time horizon which is going to affect the structure –generation mix, demand structure, grid technology, etc – of the future regional interconnected power system.

Appendix 2: Present Planning Criteria

1.5 State of the art of planning criteria in each Med-TSO member

In order to know and share the main planning criteria considered in each Med-TSO member, a survey of the state of the art in each country was required.

Among the 18 countries members of Med-TSO, 14 have responded to the survey and provided information about Main Planning Criteria considered in their systems. Therefore, the current situation at the 14 power systems in the Mediterranean Region has been collected and is included in this report.

In the following sections of the document is presented a brief description of planning criteria and/or operation limits considered by each Med-TSO member.

It's possible to underline that most of the countries have similar criteria, with particular exceptions in some cases, namely regarding with network specificities of each country. Some differences are also possible to find when comparing the countries belonging only to Med-TSO association with those belonging to the Med-TSO and ENTSO-E as well.

However, it is possible to conclude that all TSOs develop their power systems considering:

- Long-Term period (Ten Year Network period or more in some cases);
- Steady state security analysis (load-flow calculation) taking into account:
  - ✓ Thermal limits (normal and overload for lines and transformers) and Voltage limits by the N-1 contingencies analysis (some TSOs consider N-2 contingencies or more severe contingencies in particular cases of network),
- Voltage collapse analysis,
- Short-circuit calculation, and
- Transient stability studies

To perform the studies referred above, all transmission systems in Med-TSO have defined the operation limits, like overloads, voltages and angular difference acceptability limits. These limits are defined to normal conditions and under contingency conditions.

In the next table is presented the main voltage range limits applicable at the Med-TSO region for normal operation and under contingency (only N-1 contingency) situation.

Country	**Voltage range under normal and contingency conditions (N-1) to Med-TSO region**															
	400kV				220kV				150kV				> 132kV			
	Normal Conditions		N-1 Contingency		Normal Conditions		N-1 Contingency		Normal Conditions		N-1 Contingency		Normal Conditions		N-1 Contingency	
AL	360	420	360	420	198	242	198	242	135	165	135	165	99[2)]	123[2)]	99[2)]	123[2)]
DZ	380	420	380	420	205	235	198	242	141	159	135	165	-	-	-	-
CY	-	-	-	-	198	242	198	242	118,8	145,2	118,8	145,2	-	-	-	-
EG	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
FR	380	420	380	420	200	245	200	245	-	-	-	-	-	-	-	-
GR	380	420	350	420	-	-	-	-	145,5	162	135	170	-	-	-	-
IL	---	---	---	---	---	---	---	---	---	---	---	---	-	-	-	-
IT	375	415	360	420	222	238	200	242	143	158	140	165	120[1)]	139[1)]	120[1)]	145[1)]
JO	380	420	360	44	-	-	-	-	-	-	-	-	119	145	112	-

				0												
LY	380	420	360	420	209	231	198	242	---	---	---	---	---	---	---	---
ME	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MO	380	435	375	435	209[3)]	245[3)]	205[3)]	245[3)]	135	165	135	165	-	-	-	-
PS	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PT	380	420	372	420	209	245	205	245	142	165	140	165	-	-	-	-
SI	380	415	-	420	220	240	-	245	-	-	-	-	104,5[2)]	121[2)]	-	123[2)]
ES	390	420	380	435	205	245	205	245	-	-	-	-	-	-	-	-
TN	380	420	372	428	209,25	240,75	202,5	247,5	139,5	160,5	135	165	83,7[4)]	96,3[4)]	81[4)]	99[4)]
TR	370	420	340	420	-	-	-	-	146[5)]	162[5)]	140[5)]	170[5)]	-	-	-	-

NOTES: 1) Nominal Voltage = 132kV 2) Nominal Voltage = 110kV 3) Nominal Voltage = 225kV 4) Nominal Voltage = 90kV 5) Nominal Voltage = 154kV
- not applicable --- information not provided

Table 1 Voltage limits under normal and N-1 contingency condition (at the Med-TSO region)

Regarding the thermal limits (normal and overhead) for lines and transformers, different values were provided by members of the Med-TSO, and some of them were provided values for different seasons too (winter, summer, etc.). However, it is possible to summarize that in most TSOs consider 100% of load on lines and transformers in normal operation and overload among 10% to 25% under contingency situation. In the next sections is presented the operation limits (overload acceptability limits) for different countries.

1.6 Main planning criteria/limits to TSO of Albania (OST)

1.6.1 General planning criteria

Planning of the transmission system development represents the basis for all further detailed Planning of the Albanian Power System. The Ten Year Network Planning period is based on the forecasts of electricity Demand and Generation, peak load and the reduction of losses. It takes into consideration providing necessary capacities for supplying the distribution system and eligible customers directly connected to the transmission grid, transmission of electricity generated by power plants, transitions and exchanges of electricity with neighboring countries.

In order to incorporate future uncertainties in the planning process, a number of representative planning scenarios are built, relevant for assessing the overall behavior and dimensioning of the transmission system. Selected planning scenarios are analyzed using general methodologies for system analysis (network studies) and evaluated based on standard technical criteria.

The most common planning criteria considered by OST, focused on steady state security analysis, are detailed below:

- **Thermal limits** (normal and overload) of the equipment: base case and all single contingencies must not result in a permanent excess of the permissible rated limits of network equipment (as defined in the Albanian Transmission Code).
- **Voltage limits:** base case and all single contingencies must not result in permanent violation of the permissible voltages limits (as defined in the Albanian Transmission Code) in the busbars of all transmission system substations.
- **Security:** N-1 Contingency criterion is applied on the level of 400 kV, 220 kV and 110 kV of Transmission system.

1.6.2 Topological conditions to consider

The main system topological conditions considered in network studies for the assessment of planning criteria are listed below:

- **Base case topology**, in which all system elements are considered in operation, taking into account new transmission projects with a commissioning date within the examined horizon.
- **Normal contingency case topology**, in which the N-1 criterion is examined (based on Technical Criteria for Planning).

In some cases can be examined more severe contingencies, than those considered under the N-1 criterion.

1.6.3 Criteria for stability studies:

In addition to the above mentioned studies, stability analysis is also performed by OST. The main criteria considered for stability analysis are listed below:

- **Frequency Stability**: the loss of the largest loaded unit must not result in the loss of system frequency stability.
- **Transient stability:** three phase short circuits with subsequent fault clearing (N-1 element) in the busbars of the major transmission system substations must not result in the loss of synchronization for any generating unit.

1.6.4 Operation limits (overload acceptability limits, voltage and angular difference)

The thermal limits of overhead transmission lines, cables and transformers are considered, in accordance to equipment specifications. For the all seasons are used the same limits (summer – winter) for overhead transmission lines.

In the Table 2 is summarized the voltage limits considered both under normal operation conditions and under N-1 contingencies, according to the Albanian Transmission Code.

	Normal Conditions	N-1 Contingency
400 kV	360-420 kV	360-420 kV
220 kV	198-242 kV	198-242 kV
150 kV	135-165 kV	135-165 kV
110 kV	99-123 kV	99-123 kV

Table 2 *Voltage limits in normal conditions & under N-1 Contingency (AL)*

Concerning angular difference, a maximum value of 30 degrees is considered in order to ensure the ability of circuit breakers for reclosing, without imposing unacceptable step changes on local generation.

1.7 Main planning criteria/limits to TSO of Algeria (SONELGAZ)

1.7.1 General planning criteria:

Development studies of the electricity transmission network are based on data including the following:

- Demand forecasts (10 year period)
- Indicative plan of power generation needs;
- Country's economic development plan (industry, housing program, ...);
- Specific information for customers connected to networks;
- Nodal load forecast by substations for the electricity transmission network;
- The statistics data concerning performance of power generation and transmission system.

A. Studies of electricity transmission network development :

The Electricity Transmission System Development studies are developed with the aim to determine the transmission network of electricity reinforcements to ensure the safety, reliability, security and stability of the Power generation and transmission system through:

- The definition of the development plan for the Electricity Transmission System in line with the indicative plan of power generation established by the Regulatory Commission in accordance with law;
- The evaluation of reinforcements projects of the Electricity Transmission System to provide the required reliability;

Development studies of the Electricity Transport Network, conducted annually, examine:

- The behavior of the Electricity Transmission System during normal conditions and unavailability of power generation and transmission equipment;

- The behavior of the Electricity Transmission System in the presence of electromechanical or electromagnetic transients phenomena induced by disturbances or during operations of openings / closings of one or more elements of the Electricity Transport Network.

Technical studies described above are used to perform the development studies of the Electricity Transmission Network:

A.1) Load Flow Studies:

Evaluation of system behavior to the demand forecasting conditions in times of Maximum and Minimum Load and analysis of the Electricity Transmission System in the presence of new power plants and new electricity transmission connections.

A.2) short circuit studies:

These studies evaluate the risk and the ability of materials and equipment to face the circuit current in an electrical fault on one or more points in the network.

A.3) Reliability Analysis:

Reliability analysis is developed to verify the adequacy supply – demand of an electric system and network capacity to meet forecast demand. Reliability is measured by the use of probabilistic methods, using as criteria the LOLP (load loss probability) and / or EENS (energy not supplied)

B. Criteria for electricity transmission network development :

The general criteria considered for development studies of the electricity transmission network are of two types:

B.1) Security Analysis Criteria Electricity transmission network:

These deterministic character criteria are used to evaluate the carrying capacity of electricity network to cope with disturbances such as short circuits or unanticipated loss of elements of the electricity transmission network:

- **'N' Criterion:**

'N' situation where all the equipment of the electricity transmission network is available, the development of the electricity transmission network is performed to ensure the transmission of the power generation units to the consumptions areas. For this criterion, the electricity transmission network must operate within:

- The economic capacity of the electricity transmission facilities,
- Voltage admissible limits in all equipments network;
- And stability of the electrical system.

The technical conditions and constraints considered in the evaluation of the safety analysis of the electricity transmission network for criterion N are:

- All electricity transmission facilities available and in operation;

- The loading levels of the electricity transmission facilities should not exceed the rated capacity of the transformers, the economic capacity (80% of nominal capacity) of transmission lines for different seasons of the year.
- The voltage levels in main substations must be maintained within acceptable limits (see section 1.7.4).
- The stability of the electrical system must be maintained in case of disturbances on the electrical network;
- The entire electricity demand must be met at different points in the network;
- In case of disturbances on the electrical system, triggering cascading network element must not occur.

➢ **'N-1' Criterion:**

The development of electricity transmission network is designed so that the transmission system in 'N-1' situation (single failure of a line, transformer or power generation unit) is able to carry the power generation units to the consumption area.

The conditions and technical requirements considered for the safety analysis of the electricity transmission network situation 'N-1', are:

- For failure of a component of the electricity transmission network (line, transformer or generating unit); the loading rate of transmission lines remaining in service shall not exceed 100% of the permanent rated capacity of lines.
- Simultaneous failure of two circuits of lines with one tower, may not cause stability problems of the electricity transmission network, whose operation must remain within the permissible margins;
- Simultaneous failure of one power generation unit in a region and an interconnection line with other regions, should not affect the stability of the overall electrical system while maintaining the operating parameters within the permissible margins.
- The entire electricity demand must be met at different points in the network;
- In case of disturbances on the electrical system, triggering cascading network element must not occur.

  The voltage levels in substations with failure situation must be kept within the limits described in the section 1.7.4).

B.2) Adequation criteria of Power generation - Electricity Transmission systems:

These probabilistic criteria are used to assess the ability of the electricity transmission grid to meet demand for electricity taking into account the unavailability of hazards of the components of the Power generation production units - Transmission network:

➢ **Probabilistic criteria:**

The adequacy of the Power generation - Transmission electricity system is checked for the following probabilistic criteria, if any of these criteria is not verified, the strengthening of the network will be triggered:

- EENS (Expected Energy Not Supplied) by Power generation - Transmission system following the unavailability of a component of the electricity transmission network must be within margin 1 to 1,5x10-4 per unit (pu).

- LOLE (Loss Of Load Expectation), the number of hours over a period of a year for which the peak demand cannot be covered is a maximum of 48 hours.

- LOLP, The value of the probability of not being able to cover the annual peak load demand of the electrical system due to a lack of available capacity, corresponding to a threshold value of 48 hours / year.

1.7.2 Topological conditions to consider:

The main system topological conditions considered in development network studies for the assessment of planning criteria are listed below:

- **Base case topology**, in which all system elements are considered in operation, taking into account new transmission projects with a commissioning date within the examined horizon.

- **Contingency case topology**, in which the N-1 criteria are examined.

1.7.3 Criteria for stability studies:

In addition to the above mentioned studies, main stability analysis is also performed as below:

1. transient stability studies:
Transient stability studies are developed to determine the impact on the power generation - electricity transmission system of a configuration changes and / or topology of the transmission network and the capability of this system to regain a stable operating point following a transient disturbance.

2. Stability Analysis Static:
These studies are performed to determine whether the Electricity Production -Transportation System is vulnerable to static stability problems, such as oscillations inter areas for example.

3. voltage stability analysis:
These studies are designed to test the vulnerability of the transmission network to a voltage collapse in conditions of high load and for certain configurations of the network topology. Such studies are used to identify solutions to be implemented in the aim to ensure the voltage plan under the required conditions, such as the installation of reactive power compensation equipment.

4. analysis of electromagnetic transient:

Electromagnetic transient studies are developed in cases where the currents of very short duration transients and could affect the insulation of equipment, heat dissipation capacity of the capability of protection.

1.7.4 Operation limits (overload acceptability limits, voltage and angular difference)

Under normal conditions and under contingency conditions the loading rates of lines and transformers must be in the admissible limits. The load limits are mentioned in table bellow,

Items	Load (%) Normal operating conditions	Overload (%) Contingencies operating conditions (N-1)
Lines	80%	100%
Transformers	80%	100%

Table 3 Overloads allowed for lines and transformers under contingency (DZ)

In normal conditions the voltage levels in main substations must be maintained within acceptable limits.

Voltages levels	Limites (kV)	
	Min	Max
400 kV	380	420
220 kV	205	235
150 kV	141	159

Table 4 Voltage limits in normal conditions (DZ)

In under contingency conditions the voltage levels, the main substations must be maintained within acceptable limits.

Voltage levels	Limites de tension (kV)	
	Min	Max
400 kV	380	420
220 kV	198	242
150 kV	135	165

Table 5 Voltage limits under N-1 Contingency (DZ)

1.8 Main planning criteria/limits to TSO of Cyprus (Cyprus TSO)

1.8.1 General planning criteria

Planning of transmission system development focuses on the long-term adequacy and capacity of the transmission system to serve the expected load conditions, as derived from the long term Load Forecast (10 year period) and detailed load flow analysis performed by Cyprus TSO.

Network studies carried out focus on steady state security analysis. A number of alternative grid operational and economic conditions are considered in order to ensure the efficient operation of the transmission grid in the future.

The most common planning criteria considered, are detailed below:

- **Security:** N-2 Contingency criterion is applied on the backbone of the Transmission system, while the N-1 Contingency criterion is applied on the rest of Transmission system.
- **Thermal limits** (normal) of the equipment: base case and all single contingencies must not result in a permanent excess of the permissible rated limits of network equipment (as defined in the Cyprus Grid Code).
- **Voltage limits:** base case and all single contingencies must not result in permanent violation of the permissible voltages limits (as defined in the Cyprus Grid Code) on the busbars of all transmission system substations.

1.8.2 Topological conditions to consider:

The main system topological conditions considered in network studies for the assessment of planning criteria are listed below:

- **Base case topology**, in which all system elements are considered in operation, taking into account new transmission projects with a commissioning date within the examined horizon.
- **Normal contingency case topology**, in which the N-2 and N-1 criteria are examined (as described in §4.2.1).

More severe contingencies than those considered under the N-2 and N-1 criteria, can also be examined, based on the probability of occurrence and severity of consequences.

1.8.3 Criteria for stability studies:

In addition to the above mentioned studies, stability analysis is also performed by Cyprus TSO. The main criteria considered for stability analysis are listed below:

- **Frequency Stability**: the loss of the largest loaded unit must not result in the loss of system frequency stability.

- **Transient stability:** three phase short circuits with subsequent fault clearing (N-1 element) in the busbars of the major transmission system substations must not result in the loss of synchronization for any generating unit.

1.8.4 Operation limits (overload acceptability limits, voltage and angular difference)

Load flow analysis both under normal conditions and under contingency conditions should be carried out to check the compliance with the operation limits.

Table 6 summarizes the Overload limits considered both under normal operation conditions and under N-1 or N-2 contingencies, according to the Cyprus Grid Code

	Normal conditions	N-1	N-2
Lines	Winter : 10% Summer : 0 %	Winter : 10% Summer : 0 %	Winter : 10% Summer : 0 %
Transformers	According to IEC Standards	According to IEC Standards	According to IEC Standards

Table 6 Overloads allowed for lines and transformers under contingency (CY)

Table 7 summarizes the voltage limits considered both under normal operation conditions and under N-1 and N-2 contingencies, according to the Cyprus Grid Code

	Normal conditions	N-1	N-2
220 kV	198-242 kV	198-242 kV	198-242 kV
132 kV	118,8-145,2 kV	118,8-145,2 kV	118,8-145,2 kV
66 kV	62,0-70,0kV	62,0-70,0kV	62,0-70,0kV

Table 7 Voltage limits under normal and under contingency conditions (CY)

Concerning angular difference, a maximum value of 10 degrees is considered in order to ensure the ability of circuit breakers for reclosing, without imposing unacceptable step changes on local generation.

1.9 Main planning criteria/limits to TSO of Egypt (EETC)

Information not provided.

1.10 Main planning criteria/limits to TSO of France RTE)

1.10.1 General planning criteria

Planning of transmission system development focuses on the long-term scheduling of reinforcements and expansions to the existing transmission grid. In this process, uncertainties on future developments on both the production and demand sides, as well as a number of alternative grid operational conditions have to be considered to ensure the secure and efficient operation of the transmission grid in the future.

In order to incorporate future uncertainties in the planning process, a number of representative planning scenarios are built, relevant for assessing the overall behaviour and dimensioning of the transmission system. Selected planning scenarios are analysed using general methodologies for system analysis (network studies) and evaluated based on standard technical criteria.

Network studies curried out by RTE focus on steady state security analysis, in which the most common planning criteria considered.

For each grid development the main drivers used are:

1. **Security of supply**:

    Thermal limits (normal and overload) of the equipment: base case and all single contingencies must not result in a permanent excess of the permissible rated limits of network equipment. In order to take into account the impact of extreme weather conditions (high temperatures with long duration during the summer period) on system equipment, considers three different thermal limits (summer, winter, and in between) for overhead transmission lines.

    Voltage limits: base case and all single contingencies must not result in permanent violation of the permissible voltages limits in the busbars of all transmission system substations.

    Cascade tripping: A single contingency must not result in any cascade tripping that may lead to a serious interruption of supply within a wide-spread area (e.g. further tripping due to system protection schemes after the tripping of the primarily failed element).

2. **Cost of the project and the return on investment**

3. **Quality of electricity**

4. **Assess management:** the grid development have to be optimized with the life expectancy of each power lines.

5. **Environmental assessment of the project**

1.10.2 Topological conditions to consider:

The main system topological conditions considered in network studies for the assessment of planning criteria are:

- **Base case topology**, in which all system elements are considered in operation, taking into account new transmission projects with a commissioning date within the examined horizon. The grid is most of the time a "hierarchical" grid. The 225, and below voltage power lines aren't used as a loop.

- **Normal contingency case topology**, in which the N-1 criterion is examined.

More severe contingencies, than those considered under the N-1 criterion, can also be examined in some cases defined by RTE, based on the probability of occurrence and severity of consequences, such as busbar failure in a substation, multiple independent failures, outages or failure combined with maintenance.

Sensitivity analysis may also be considered, under the hypothesis of delays in the commissioning dates of new transmission projects, in order to investigate the secure operation of the transmission network within the examined horizon.

1.10.3 Criteria for stability studies:

In addition to the above mentioned studies, stability analysis is performed by RTE for main investment projects. The main criteria considered for stability analysis are listed below:

- Multiple dynamic performance checks to assess stability limits
- Other dynamic checks like hypo-synchronic stability studies (especially with the implementation of DC lines near other DC lines or thermal power plants).

1.10.4 Operation limits (overload acceptability limits, voltage and angular difference)

ENTSO-E works on common rules for grid operational planning and scheduling. http://networkcodes.entsoe.eu/

Voltage kV	Normal operating conditions		Contingencies operating conditions (N-1)	
	Min	Max	Min	Max
400 kV	380	420	380	420
225 kV	200	245	200	245

Table 8 Voltage limits under contingency (FR)

1.11 Main planning criteria/limits to TSO of Greece (IPTO)

1.11.1 General planning criteria

Planning of transmission system development focuses on the long-term scheduling of reinforcements and expansions to the existing transmission grid. In this process, uncertainties on future developments on both the production and demand sides, as well as a number of alternative grid operational conditions have to be considered to ensure the secure and efficient operation of the transmission grid in the future.

In order to incorporate future uncertainties in the planning process, a number of representative planning scenarios are built, relevant for assessing the overall behaviour and dimensioning of the transmission system. Selected planning scenarios are analysed using general methodologies for system analysis (network studies) and evaluated based on standard technical criteria.

Network studies carried out by IPTO focus on steady state security analysis, in which the most common planning criteria considered, are detailed below:

- **Thermal limits** (normal and overload) of the equipment: base case and all single contingencies must not result in a permanent excess of the permissible rated limits of network equipment (as defined in the Greek Grid Code). In order to take into account the impact of extreme weather conditions (high temperatures with long duration during the summer period) on system equipment, IPTO considers two different thermal limits (summer and winter) for overhead transmission lines.
- **Voltage limits:** base case and all single contingencies must not result in permanent violation of the permissible voltages limits (as defined in the Greek Grid Code) in the busbars of all transmission system substations.
- **Cascade tripping:** A single contingency must not result in any cascade tripping that may lead to a serious interruption of supply within a wide-spread area (e.g. further tripping due to system protection schemes after the tripping of the primarily failed element).

1.11.2 Topological conditions to consider

The main system topological conditions considered in network studies for the assessment of planning criteria are listed below:

- **Base case topology**, in which all system elements are considered in operation, taking into account new transmission projects with a commissioning date within the examined horizon.
- **Normal contingency case topology**, in which the N-1 criterion is examined (as described in §4.2.1).

More severe contingencies, than those considered under the N-1 criterion, can also be examined in some cases defined by IPTO, based on the probability of occurrence and severity of consequences, such as busbar failure in a system substation, multiple independent failures or failure combined with maintenance.

Sensitivity analysis may also be considered, under the hypothesis of delays in the commissioning dates of new transmission projects, in order to investigate the secure operation of the transmission network within the examined horizon.

1.11.3 Criteria for stability studies

In addition to the above mentioned studies, stability analysis is also performed by IPTO. The main criteria considered for stability analysis are listed below:

- **Transient stability:** three phase short circuits with subsequent fault clearing (N-1 element) in the busbars of the major transmission system substations must not result in the loss of synchronization for any generating unit.
- **Small signal stability:** sufficient damping must exist for local and inter-area oscillations triggered by small disturbances.

It should be mentioned that for the examination of criteria relevant to the stability (in particular small signal stability) of the Hellenic power system, a power system model of the Continental South Eastern Europe area is considered. Additional stability criteria might be used for specific studies. For example, one of the most important transmission projects concerns the interconnection of the island of Crete to the mainland transmission system. In this respect, dynamic studies have been carried out in order to assess the power transfer limit between the Mainland and the island of Crete that does not jeopardize frequency stability of the island power system of Crete in the case of loss of the interconnection.

1.11.4 Operation limits (overload acceptability limits, voltage and angular difference)

The thermal limits of overhead transmission lines, cables and transformers are considered, in accordance to equipment specifications. As mentioned above seasonal limits (summer – winter) are considered for overhead transmission lines.

Voltage limits considered under normal operation and contingency conditions (N, N-1, N-2), are summarized in the table below, in accordance to the Grid Cod.

	Normal conditions	Contingency conditions
400 kV	380-420 kV	350-420 kV
150 kV	145.5-162 kV	135-170 kV

Table 9 Voltage limits under normal and contingency conditions(GR)

Concerning angular difference, a maximum value of 30 degrees is considered in order to ensure the ability of circuit breakers for reclosing, without imposing unacceptable step changes on local generation.

1.12 Main planning criteria/limits to TSO of Israel (IEC)

(waiting for more information)

1.13 Main planning criteria/limits to TSO of Italy (TERNA)

1.13.1 General planning criteria

The official document for the planning of the Italian power systems is the National Grid Code. It contains the planning criteria and rules for the grid planning as well as the connection of users/generators to the national transmission grid. The planning is carried out both at National and European (ENTSO-E) level (as part of an interconnected regional system). Planning horizons used for the transmission power system planning varies from 10 years (national planning) to more than 15 years (ENTSO-E planning). To take into account uncertainties during transmission network planning a multi-scenario approach is adopted for the analyses.

The analyses performed by Terna for transmission network planning are mainly:

- Load-flow
- Security analysis (N-1 contingencies)
- Short-circuit calculation
- Stability simulations
- Optimum power flows (OPF)

The major investments in transmission grid infrastructures are assessed by a cost benefit analysis (CBA) according to the national and ENTSO-E rules. The main benefits estimated are:

- RES integration
- Reduction of electricity market price (Reduction of grid congestions costs, re-dispatching costs, etc.)
- Improving of SoS
- Reduction of GHG emissions cost
- Reduction of losses cost
- Delta-investment costs (comparing development solutions)
- Reduction of O&M costs

For interconnection lines additional Ad-hoc studies could be performed to evaluate the contribution and benefits in terms of markets integration/security of supply of a new interconnection based on a specific model.

1.13.2 Topological conditions to consider

The criteria applied for transmission network studies are based on deterministic an probabilistic studies as well as N-1 contingencies studies. Different thermal ratings for lines and transformers are considered during winter and summer period. The winter thermal rating for OHL is greater than the summer one to take into account the thermal expansion of the power conductors catenaries.

The software used for transmission network planning is SPIRA, a tool developed by CESI on behalf of TERNA.

The N-1 criterion applied is related to the loss of single-circuit lines, double-circuit lines, transformers and generators. The events not allowed to happen during n-1 operational conditions are thermal overloading of branches and voltage declination exceeding permitted range (see ph. 2.8.4). In particular, the lines which have in N conditions a current I≤ 80% In (rating current) can work in N-1 condition with a I≤ 120% for a limited period (about 20 mins). Transformers can work with I ≤ 110% In in N-1 conditions for a limited period of times.

1.13.3 Criteria for stability studies

Stability limits are also considered in the modelling of grid elements.

1.13.4 Operation limits (overload acceptability limits, voltage and angular difference)

Voltage variation range:

Voltage	Normal operating conditions		Contingencies operating conditions (N-1)	
	Min [kv]	Max [kV]	Min	Max
400 kV	**375**	**415**	**360**	**420**
220 kV	**222**	**238**	**200**	**242**
150 kV	**143**	**158**	**140**	**165**
132 kV	**120**	**139**	**120**	**145**

Table 10 Voltage limits under contingency (IT)

Load and overload limits of lines and transformers:

Items	Load (%) Normal operating conditions	Overload (%) Contingencies operating conditions (N-1)
Lines	**100%**	**120% ***
Transformers	**100%**	**110%**

*The lines which have in N conditions a current I≤ 80% In (rating current) can work in N-1 condition with a I≤ 120% for a limited period (about 20 mins).

Table 11 Overloads allowed for lines and transformers under contingency (IT)

1.14 Main planning criteria/limits to TSO of Jordan (NEPCO)

(waiting for more information)

1.15 Main planning criteria/limits to TSO of Libya (GECOL)

1.15.1 General planning criteria:

The state owned General Electricity Company of Libya (GECOL) is solely responsible to develop and update electricity transmission network with objects to:

- Collect and verify the system data to build up a model of the transmission network
- Analyze the existing transmission system to determine its capability and weakness points
- Plan an adequate, strong transmission network to ensure the transport of electric power from generators to areas of customer demand under a wide variety of expected system operating conditions
- Design a transmission network, which is capable to transport power flows from and to neighboring countries.

The principal factors that drive the need for transmission network development in Libya are:

- Demand growth
- New generation connections and retirements
- New connections of transmission lines and substations
- New tie lines interconnections to neighboring countries

1.15.2 Transmission Planning Studies

Power system planning studies are conducting to decide where and when to add the new power system elements needed for reliable and economic supply of bulk power from remote sites into cities and towns, the following studies are the main ones used for Libyan electricity transmission system.

1.15.2.1 Load Flow Studies

Load flow studies are conducted for the Libyan transmission system to investigate the future system performance under various load conditions (maximum load and minimum load) and for N normal conditions and N-1 contingency conditions (N-1 contingency conditions were analyzed for outage of each network element in the system).

All load flow cases are simulated according to these criteria and main assumptions conditions:

- Ensure that the voltage profile of the system is maintained within the acceptable limits of ±5% voltage variation for normal operating conditions and +5% / -10% voltage variation for 400kV (±10% for 220kV) for contingency operating conditions.
- The generator power output should not exceed the capability limits.
- In all 400 kV stations a minimum number of two 400/220 kV transformers (400 MVA each) has been considered.
- The maximum power flow in the transformers should not exceed the rated MVA capacity.
- The power flow on transmission lines should not exceed the maximum admissible line current.

1.15.2.2 Short Circuit Studies

Short circuit analysis is done to calculate the magnitude of current levels flowing throughout the power system for bolted three-phase and single-phase to earth faults in a power system, two operating system conditions is investigated (maximum and minimum load condition). To ensure that the existing and newly installed breakers will not be overstressed or fail to protect the system under short circuit conditions, and to determine and evaluates the size and settings of a system's protective devices, such as relays, circuit breakers, and the circuits they protect and to assist in system planning.

1.15.2.3 Reliability analysis Studies

Power system reliability analysis studies assure that the power system is well designed to perform and fulfill its function adequately and securely for the period of time and operation conditions intended.

1.15.3 Topological conditions to consider

The main system topological conditions considered in development network studies for the assessment of planning criteria are listed below:

- **Base case topology**: in which all system elements are considered in operation, taking into account new transmission projects with a commissioning date within the examined horizon for both maximum and minimum loading conditions.
- **Contingency case topology**: in which the N-1 and N-2 contingency conditions are analyzed for both maximum and minimum loading conditions.

1.15.4 Criteria for stability studies

In addition to the above-mentioned studies, main stability analysis is also performed as below:

1.15.4.1 Transient Stability Studies

The transient stability studies is conducted to investigate and verify that the Libyan electrical transmission system performance under various conditions and contingencies (e.g. short circuits, sudden change in generation or load …etc.), is stable and within acceptable security limits.

In addition, these studies used extensively in planning any reinforcement requirements to improve system stability behavior during faults.

As a general rule, Libyan electrical transmission system must not goes into oscillation and losing stability following credible dynamic faults shown below:

- Outage of 400 and 220 KV lines without short circuit.
- Outage of 400 and 220 KV lines following three phase short circuit (100 MS of duration).
- Bus-bar section outages following single phase short circuit (300 MS of duration) and tripping a quarter of all connections.
- Loss of the largest generating unit.
- Drop of the largest load.

1.15.4.2 Steady State Voltage Stability Studies

The main aim of this study is to check the capability of the Libyan electrical transmission system to maintain the voltage profile at all buses in the presence of slow and small variation of the system loads (in normal and N-1 contingency conditions) to avoid a voltage decline as a result of reactive power deficiency. Voltage stability is load stability, related to load demand versus load supply capability. A possible outcome of voltage instability is loss of load in a region or tripping transmission lines and other elements by their protective system. The objectives is to find the type, size an d location of voltage control devices so the reactive power needs to be managed or compensated in a way to ensure sufficient amounts are being produced to meet demand and so that the electric power system can run efficiently.

1.15.4.3 Insulation Coordination Studies

Insulation coordination or insulation design is very important in constructing and operating the transmission system in an economic and reliable way. The field of insulation coordination can be divided into the coordination of transmission lines and substation. The main goal is to select insulation strength (minimum insulation strength or minimum clearance) compared to the expected overvoltage taking into account the service environment and the protective devices characteristic and availability.

1.15.5 Operation limits (overload acceptability limits, voltage and angular difference)

Under normal conditions and under contingency conditions the loading rates of lines and transformers must be in the admissible limits. The load limits are mentioned in table bellow,

Items	Load (%) Normal operating conditions	Overload (%) Contingencies operating conditions (N-1)
Lines	100%	100%
Transformers	100%	100%

Table 12 Overloads allowed for lines and transformers under contingency (LY)

In normal conditions the voltage levels in main substations must be maintained within acceptable limits.

Voltages levels	Voltage Limits (kV)	
	Min	Max
400 kV	380	420
220 kV	209	231

Table 13 Voltage limits in normal conditions (LY)

In under contingency conditions the voltage levels, the main substations must be maintained within acceptable limits.

Voltage levels	Voltage Limits (kV)	
	Min	Max
400 kV	360	420
220 kV	198	242

Table 14 Voltage limits under N-1 Contingency (LY)

1.16 Main planning criteria/limits to TSO of Montenegro (CGES)

(waiting for more information)

1.17 Main planning criteria/limits to TSO of Morocco (ONEE)

1.17.1 General planning criteria

Planning of transmission system development focuses on the long-term adequacy and capacity of the transmission system to serve the expected load conditions, as derived from the long term Load Forecast (10 year period) and detailed load flow analysis performed by ONEE (TSO of MOROCCO).

Network studies carried out focus on steady state security analysis. A number of alternative grid operational conditions are considered in order to ensure the efficient operation of the transmission grid in the future.

The most common planning criteria considered, are detailed below:

- **Security:** N-1 Contingency criterion is applied on the Transmission system 400kV, 225kV and 60kV.
- **Thermal limits** (normal) of the equipment: base case and all single contingencies must not result in a permanent excess of the permissible rated limits of network equipment.
- **Voltage limits:** base case and all single contingencies must not result in permanent violation of the permissible voltages limits on the busbars of all transmission system substations.

1.17.2 Topological conditions to consider:

The main system topological conditions considered in network studies for the assessment of planning criteria are listed below:

- **Base case topology**, in which all system elements are considered in operation, taking into account new transmission projects with a commissioning date within the examined horizon.
- **Normal contingency case topology**, in which the N-1 criteria are examined.

1.17.3 Criteria for stability studies:

In addition to the above mentioned studies, stability analysis is also performed by ONEE. The main criteria considered for stability analysis are listed below:

- **Frequency Stability**: the loss of the largest loaded unit and the loss of the largest unit of generation must not result in the loss of system frequency stability.
- **Transient stability:** three phase short circuits with subsequent fault clearing (N-1 element) in the busbars of the major transmission system substations must not result in the loss of synchronization for any generating unit.

1.17.4 Operation limits (overload acceptability limits, voltage and angular difference)

Load flow analysis both under normal conditions and under contingency conditions should be carried out to check the compliance with the operation limits.

Table 15 summarizes the Overload limits considered both under normal operation conditions and under N-1 contingencies,

Items	Load (%) Normal operating conditions	Overload (%) Contingencies operating conditions (N-1)
Lines	100%	120%
Transformers	100%	120%

Table 15 Overloads allowed for lines and transformers under contingency (MO)

Table 16 summarizes the voltage limits considered both under normal operation conditions and under N-1 contingencies,

Voltage	Normal operating conditions		Contingencies operating conditions (N-1)	
	Min	Max	Min	Max
400 kV	380	435	375	435
225 kV	209	245	205	245
150 kV	135	165	135	165
60 kV	54	66	54	66

Table 16 Voltage limits under contingency (MO)

1.18 Main planning criteria/limits to TSO of Palestine (PETL)

(waiting for more information)

1.19 Main planning criteria/limits to TSO of Portugal (REN)

1.19.1 General planning criteria

Power Systems Planning in Portugal is regulated by rules and criteria that define the "Safety Standards for Planning of National Transmission Grid (RNT)[2]" established in Article 36 of Decree-Law 172/2006 of 23rd August.

National Development Plans (NDPs) are approved by the Portuguese Government after a proposal made by the System Operator. Before approval of the Portuguese Government, NDP is submitted to a public consultation and a National Regulator Entity opinion is needed.

[2] Padrões de segurança para planeamento da Rede Nacional de Transporte (RNT), previstos no artigo 36.º do Decreto-Lei n.º 172/2006, de 23 de Agosto.

The main objective of Transmission Grid Development and Investment Plan (PDIRT) is to anticipate the needs for the development of RNT so as to ensure future sustainability, with the main focus set on the following vectors:

(i) security and quality of supply;

(ii) the existence of delivery and reception capacity of electricity that enables secure implementation of major energy policy objectives;

(iii) the obligations of the development of electricity markets (MIBEL for the Iberian zone and "Ten-Year Network Development Plan" 'TYNDP' for the European network), aiming to promote an increasing European integration.

Planning time horizons used for the transmission power system planning in Portugal are 10 years national planning and more than 15 years in ENTSO-E planning. To take into account uncertainties during transmission network planning a multi-scenario approach is adopted for the analysis performed by REN (TSO of Portugal).

The analyses performed by REN for transmission network planning are mainly:

- Steady state security analysis (load-flow calculation) taking into account:
  Thermal limits (normal and overload for lines and transformers) and Voltage limits by the N-1, N-2 contingencies analysis
  - Voltage collapse analysis,
  - Short-circuit calculation
  - Transient stability simulations
  - Optimum power flows (OPF)

1.19.2 Topological conditions to consider

The planning scenarios are defined in order to characterize technical and economic representative conditions.

The following issues are the most important to be taken into account when building detailed network cases for planning studies in different time horizons:

- Demand and generation fluctuates through a day and through the year (e.g. Peak/Off-Peak and e. g. Winter/Summer);
- Power exchange forecasts (estimated main power exchanges with external systems);
- Specific sets of network facilities (taking into account the forecasted commissioning and decommissioning dates);
- Weather is a factor that not only influences demand and, increasingly, generation, but also the technical capabilities of the transmission network (e.g. wind, temperature, sun, etc.).
- Volatility of hydro and wind operation conditions

The main system topological conditions considered in network studies for the assessment of planning criteria are listed below:

- **Base case topology**, in which all system elements are considered in operation, taking into account new transmission projects with a commissioning date within the examined horizon.

- **Normal contingency case topology**, in which the N-1 and N-2 criteria are examined.

In these case topologies, overloads, overvoltages and undervoltages are analyzed.

More severe contingencies than those considered under the N-1 and N-2 criteria, can also be examined, based on the probability of occurrence and severity of consequences in some particular network cases.

1.19.3 Criteria for stability studies

In addition to the above mentioned studies, stability analysis is performed by REN for main investment projects, namely large power plants or new axes of transmission network. In other words, based on REN knowledge, some transient simulations (and other detailed analysis oriented to identifying possible instability) are performed in some cases where problems with stability can be expected.

The main criteria considered for stability analysis are listed below:

- **Transient stability:** three phase short circuits with subsequent fault clearing (N-1 element) in the any elements of the transmission system must not result in the loss of synchronization for any generating unit, unless in case of the short circuit directly in the power plant.

- **In addition to the disturbances mentioned above** and provide the basis for analysis of transient stability of the Portuguese grid, are also considered more severe disturbances but less likely event for the purpose of characterization of its effect on network operation and take measures to minimize the their probability of occurrence and impact. These disturbances are associated with protective systems operation in 2nd level, corresponding to the operation of the breaker failure protection or failure of Tele-protection.

- **Small signal stability:** sufficient damping must exist for local and inter-area oscillations triggered by small disturbances.

1.19.4 Operation limits (overload acceptability limits, voltage and angular difference)

Load flow analysis both under normal conditions and under contingency conditions should be carried out to check the compliance with the operation limits.

Table 17 summarizes the thermal limits considered both under normal operation conditions and under N-1 or N-2 contingencies, according to current security practices in Portugal [RNT Planning Safety Standards – "Ordinance n.º 596/2010"]

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

Table 17 Overloads allowed for lines and transformers under contingency (PT)

Table 18 summarizes the voltage limits considered both under normal operation conditions and under N-1 and N-2 contingencies, according to current security practices in Portugal [RNT Planning Safety Standards – "Ordinance n.º 596/2010"].

	Normal conditions	N-1	N-2
400 kV	380-420 kV	372-420 kV	360-420 kV
220 kV	209-245 kV	205-245 kV	198-245 kV
150 kV	142-165 kV	140-165 kV	135-165 kV

Table 18 Voltage limits under contingency (PT)

Concerning angular difference, a maximum value of 25/30[4] degrees is considered in order to ensure the ability of circuit breakers for reclosing, without imposing unacceptable step changes on local generation.

[3] All lines of 400 kV network, as well as the remaining lines that feed the "Large Lisboa area" and Setúbal peninsula, are included in the Overload Category B, and therefore cannot be subject to overloads temporary. However, the evolution of the structure of RNT may lead to the inclusion of other lines in this category, particularly in the "Large Porto area" when and if the 150 kV lines are decommissioned.

[4] 25º is applied for the 220 kV and 150 kV internal network;
30º is applied for the 400kV internal network and for interconnection overhead lines.

1.20 Main planning criteria/limits to TSO of Slovenia (ELES)

1.20.1 General planning criteria

The main goal of the transmission system planning is to ensure safe and reliable operation in long term horizon. In addition, it is necessary to take into account economic efficiency, non-discriminatory access, market liberalization and the implementation of appropriate standards, requirements and directives.

Planning development is carried out periodically depending on the needs. There are two time horizons considered in the development area of the transmission system and are medium-term (five to seven years) and long term (ten to fifteen years).

Transmission network planning begins with the creation of scenarios, which provide transmission network topology, production, demand and transit power flows during certain time periods.

The most common planning criteria considered in ELES, are detailed below:

- **Thermal limits** (normal and overload) of the equipment: base case and all single contingencies must not result in a permanent excess of the permissible rated limits of network equipment.
- **Voltage limits:** base case and all single contingencies must not result in permanent violation of the permissible voltages limits on the busbars of all transmission system substations.
- **Short circuits**
- **Cascade tripping:** a single contingency in the system must not result in an overload of the other elements that may lead to one or more additional failures or cascade tripping.
- **Environmental impact:** extremely important due to placing the new investments in the area. Taking into account the interests of local communities it is also necessary to minimize the impact on the environment.
- **Economic aspect:** cost-benefit rate delivers the optimal development of the transmission system

1.20.2 Topological conditions to consider

The main system topological conditions considered in network studies for the assessment of planning criteria are listed below:

- **Base case topology**, in which all system elements are considered in operation, taking into account new transmission projects with a commissioning date within the examined horizon.
- **Normal contingency case topology**, in which the N-1 criterion is examined

In addition to N-1 criterion, N-2 can also be examined in case of multiple independent failures or failure combined with maintenance.

1.20.3 Criteria for stability studies:

In case of performing stability studies the main criteria considered are listed below:

- **Frequency Stability:** the loss of the largest loaded unit must not result in the loss of system frequency stability.

- **Transient stability:** three phase short circuits with subsequent fault clearing (N-1 element) in the any elements of the transmission system must not result in the loss of synchronization for any generating unit, unless in case of the short circuit directly in the power plant.

1.20.4 Operation limits (overload acceptability limits, voltage and angular difference)

Load flow analysis both under normal conditions and under contingency conditions should be carried out to check the compliance with the operation limits.

Table 19 summarizes the voltage limits considered both under normal operation conditions and under N-1 contingencies, according to current security practices in Slovenia.

Voltage [kV[	Min [kV]	Max [kV]	Max permissible voltage [kV]
400	380	415	420
220	220	240	245
110	104,5	121	123

Table 19 *Voltage limits under N and N-1 conditions (SI)*

Table 20 summarizes the thermal limits considered both under normal operation conditions and under N-1 contingencies, according to current security practices in Slovenia.

Elements	Load (%) Normal operating conditions (N)	Overload (%) Contingencies operating conditions (N-1)
Lines	**100%**	**100%**
Transformers	**100%**	**100%**

Table 20 *Overloads allowed for lines and transformers under N and N-1 conditions (SI)*

1.21 Main planning criteria/limits to TSO of Spain (REE)

1.21.1 General planning criteria

Power System Planning in Spain is regulated in *Article 4 of Law 24/2013, from the Electric Sector*, and in the following Operational Procedures:

- Transmission Grid Development Criteria.
- Transmission grid assets: equipment design criteria and minimum requirements.

-
- Operation and Security criteria for the operation of the power system.

National Development Plans (NDPs) are approved by the Spanish Government after a proposal made by the System Operator. These NDP´s include not only transmission grid new assets but also generation facilities. Anyway only transmission grid facilities are binding.

The planning period is of 6 years but NDPs should be updated each 4 years. Under special circumstances and with a previous proposal of the System Operator, the Spanish Government could approve modifications in terms of annual programs.

Main objective of this Power System Planning in Spain is determining the needs of new Generation and Transmission Assets that will be necessary to ensure power supply to all customers in the adequate security and reliability conditions and respecting the criteria regarding:

- Economic efficiency
- Highest respect for the environment.

Main objectives could be summarized as follows:

- Achieve an optimal level of electrification in the whole country.
- Continue the development of the meshing of the Grids (Peninsula and Islands).
- Continue the reinforcement of the international interconnections.
- Procure energy storage in the power system.
- Promote the development of Smart Grids and the Supergrid.
- Promote measures to increase energy efficiency.

1.21.2 Topological conditions to consider

The Planning Criteria established in the Spanish Power System can be classified as follows:

- Suitability (Eligibility) Criteria: Determination of system adequacy in steady state terms (overloads, over voltages and under voltages) in N, N-1 and N-X conditions.
- Security Criteria: Determination of system adequacy and reliability in transient/dynamic state.

1.21.3 Operation limits (overload acceptability limits, voltage and angular difference)

Load flow analysis under normal conditions (N) and under contingency conditions (N-1 and N-x) should be carried out to check compliance with operation limits.

- Voltage limits:

	Normal conditions	N-1	N-2
400 kV	390-420 kV	380-435 kV	375-435 kV
220 kV	205-245 kV	205-245 kV	200-245 kV

Table 21 Voltage limits under normal and contingency conditions (SP)

- Thermal limits:

	Normal conditions	N-1	N-2
Lines*	0%	15% but less than 20 minutes	15%
Transformers	0%	0% in summer 10% in winter	20% in winter 10% in summer 15% in rest of the year

Table 22 Overloads allowed for lines and transformers under contingency (SP)

*Special limits for international interconnection lines:

- 0% in general, with some exceptions:
  - 30% in Spain-France interconnection if contingency is the loss of a Spanish generator and only before the activation of secondary regulation.
  - For Spain-Portugal interconnection, conformity of Portuguese System Operator is needed to consider usual limits.

1.21.4 Criteria for stability studies and for other type of studies

Other criteria that are also considered are:

- Voltage collapse analysis proposing reactive compensation assets.
- Dynamic studies:
  - Sudden loss of important generation units.
  - Short circuit analysis.
  - Transient stability analysis.
  - Oscillatory stability analysis.
- Maximum capacity acceptable in transmission nodes.
- Design criteria for lines and substations:
  - Short circuit power levels: 50 kA in 400 kV and 40 kA in 220 kV.
  - Isolation levels.
  - Electric and magnetic field levels.
  - Audible noise levels.

- Configuration:
  - 400 kV substations:
    - Breaker and a half.
    - Ring configuration.
  - 220 kV substations:
    - Breaker and a half.
    - Ring configuration.
    - Double bus bar with coupling.
  - Transmission lines will be overhead unless specific requirements are needed.
- Line undergrounding criteria.
- Grid meshing criteria.
- Limitation of the number of no-meshed grid nodes .
- Minimum power to open transmission lines .
- Minimization of the length of entries/exits to transmission lines.
- Need of coordination between transmission and distribution system planning.

1.22 Main planning criteria/limits to TSO of Tunisia (STEG)

1.22.1 General planning criteria

Planning of transmission system development focuses on the mid and long-term scheduling of reinforcements and expansions to the existing transmission grid. In this process, uncertainties on future developments on both the production and demand sides, as well as a number of alternative grid operational conditions have to be considered to ensure the secure and efficient operation of the transmission grid in the future.

Three types of Network studies are carried out by STEG, in which the most common planning criteria considered, are detailed below:

1.22.2 Steady State network analyses

I. Thermal limits (normal and overload) of the equipment
Base case and all single contingencies must not result in a permanent excess of the permissible rated limits of network equipment (the Tunisian Grid Code was recently elaborated and it is under finalization).

- N situation: No permanent overloads are accepted on transmission lines, cables and transformers
- N-1 situation: Only Overloads under 20% of the rated power are accepted

Since Tunisia presents a summer peak of demand, the planning studies carried out by STEG take into account only the impact of high temperatures with long duration during the summer period for transmission lines, cables and transformers in its planning criterion. During the summer peak, even the production units are unable to produce their maximum power. For these reasons, power developed from production units is considered as below:

- Gas & gasoil Turbines: 85% of their maximum power
- Steam Turbines: 95% of their maximum power
- For reactive power, no violations of the VAR limit bands are permitted. Reactive power produced by each production unit must be covered by the PQ diagram of the unit.
- For the studies which interest for off peak conditions, thermal limits under low temperatures are considered.

II. Voltage limits:
Base case and all single contingencies must not result in permanent violation of the permissible voltages limits (as defined below) in the busbars of all transmission system substations.

Voltage	**Normal operating conditions**		**Contingencies operating conditions (N-1)**	
	Min	**Max**	**Min**	**Max**
400 kV	380	420	372	428
225 kV	209.25	240.75	202.5	247.5
150 kV	139.5	160.5	135	165
90 kV	83.7	96.3	81	99
MV	-5%U	+5%U	--	--

Table 23 Voltage limits under normal and contingency conditions (TN)

III. Topological conditions to consider
The main system topological conditions considered in network studies for the assessment of planning criteria are listed below:

- **Base case topology**, in which all system elements are considered in operation, taking into account new transmission projects with a commissioning date within the examined horizon.
- **Normal contingency case topology**, in which the N-1 and N-2 criterion are examined.

  - **N-1 Contingency**: The loss of one circuit (Transformer, line or cable)
  - **N-2 Contingency**: The loss of a production unit together with a transmission circuit.

1.22.3 Short circuit calculation:

The single phase and the three phase short circuit must remain in an accepted range (under the breaking capacity of the circuit breaker in every substation in the whole system). The calculations are done under CEI60909 standard methodology.

1.22.4 Stability studies:

I. Criteria

In addition to the above mentioned studies, stability analysis is also performed by STEG. Many aspects are simulated and verification is done as follow:

- Three phase short circuits with subsequent fault clearing (N-1 element) for the important transmission axes (OHL, cables and interconnection lines) relating production platforms to consumption must not result in the loss of synchronism for any generating unit.
- The frequency should remain within an accepted level in case of a 3 phase short circuit or the loss of the biggest unit of production in the Tunisian system.
- After the loss of a production unit or a 3 phase fault, the system must be well dumped.

It should be mentioned that for the examination of criteria relevant to the stability of the Tunisian electrical system, a power system model of the Maghreb area (Algeria and Morocco) interconnected with Europe is considered. Additional stability criteria might be used for specific studies.

II. Operation limits (overload acceptability limits, voltage)

The thermal limits of overhead transmission lines, cables and transformers must remain in an accepted level, in accordance to equipment specifications as mentioned in Thermal limits paragraph.

Voltage limits considered under normal operation and contingency conditions (N, N-1), are the same as mentioned in the Table 23.

The evolution of voltage in a consumption substation must be recovered in accepted limits (Table 23) after a 3 phase fault or the loss of a unit of production.

1.23 Main planning criteria/limits to TSO of Turkey (TEIAS)

1.23.1 General planning criteria

Transmission system planning aims to determine infrastructure requirements of electrical grid to cover consumption and generation for short and medium term. Load forecast studies for 5 and 10 years, existing network, projects in the investment plan are used to compose future transmission network. Short and medium term planning studies are conducted for different consumption and generation conditions. Loading limits of equipment and voltage limits in the network are examined for base case and contingency cases in different scenarios. Turkish Grid Code describes planning principles, design principles and operational limits of transmission network.

1.23.2 Topological conditions to consider

Mainly two topological conditions are considered in the planning studies:

- Base case (Normal operating condition): All transmission equipment in service

- (N-1) constraint: Disconnection of any equipment or interconnected equipment group of the transmission system due to failure
- In some studies (N-2) constraint is examined.
    - (N-2) constraint: The disconnection of two equipment of the transmission system independent from each other at the same time due to failures,

1.23.3 Criteria for stability studies:

Turkish Grid Code includes following articles regarding to system planning. Transient stability studies are conducted to ensure stability of transmission system and to check operation limits of system.

"The transmission system shall be planned so as to ensure that the transmission facilities will be loaded below the thermal limits, no user will be lost, the system stability will not be disturbed, and the system will not be divided into islands, ensuring that the voltage and frequency will remain within the limits set out in this Regulation in the event that the plants transfer their maximum production to the system under the normal operating conditions of the system and in the case of (N-1) constraint conditions in the system."

"In the case of (N-2) constraint conditions at the connection points of nuclear power plants to the system, it is planned so as to ensure that the transmission facilities will be loaded below the thermal limits, no user will be lost, the system stability will not be disturbed, and the system will not be divided into islands, ensuring that the voltage and frequency will remain within the limits set out in this Regulation."

1.23.4 Operation limits (overload acceptability limits, voltage and angular difference)

Voltage limits for base case (normal operating condition) and contingency cases (N-1 operating condition) are given in below table.

Voltage	Normal operating conditions		Contingencies operating conditions (N-1)	
	Min (kV)	Max (kV)	Min (kV)	Max (kV)
400 kV	370	420	340	420
154 kV	146	162	140	170

Table 24 Voltage limits under normal and contingency conditions (TR)

Loading limits for base case (normal operating condition) and contingency cases (N-1 operating condition) are given in below table.

Items	Load (%) Normal operating conditions	Overload (%) Contingencies operating conditions (N-1)
Lines	100%	100%

Table 1 *Overloads allowed for lines and transformers under contingency (TR)*

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