Deliverable 2.1.2

Detailed Project Description

13 - GRBGTR Greece-Bulgaria-Turkey

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"Mediterranean Project"

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

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1 Introduction

The present document contains the studies on project GRTRBG, in the context of the Mediterranean Master Plan of Interconnections. Project GRTRBG consists of new interconnections between Greece and Turkey (+500 MW AC) and between Bulgaria and Turkey (+500 MW AC).

The document is structured as follows. Section 2 describes in detail the interconnection project and the different sources for data employed. Section 3 presents the definition of the different snapshots to be considered and the description of the building process followed. Section 4 comprises the criteria and results of the security analysis. Section 5 summarizes the results on security analysis and reinforcements' assessment. Section 6 contains the estimations made for the active power losses. Finally, section 7 comprises the estimation for the different investment costs.

2 Project description and data acquisition

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.

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 Bulgaria 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.

Project details

Description	***Substation (from)***	***Substation (to)***	***GTC contribution (MW)***	***Present status***	***Expected commissioning date***	***Evolution***	***Evolution driver***
New interconnections between Turkey–Greece (AC) and Turkey-Bulgaria (AC)	Greece (GR) N. Santa Bulgaria (BG) Maritsa Iztok	Turkey (TR) Babaeski Turkey (TR) Hamitabat	1000	Long-term project	Project under consideration		Increase NTC in the CESA to Turkey transmission corridor.

The systems involved in the project GRTRBG are described in the table and figure below.

Full models	**Boundaries**
Greece GR	Albania AL
Bulgaria BG	Italy IT
Turkey TR	FYROM FY
	Serbia RS
	Romania RO
	Syria SY

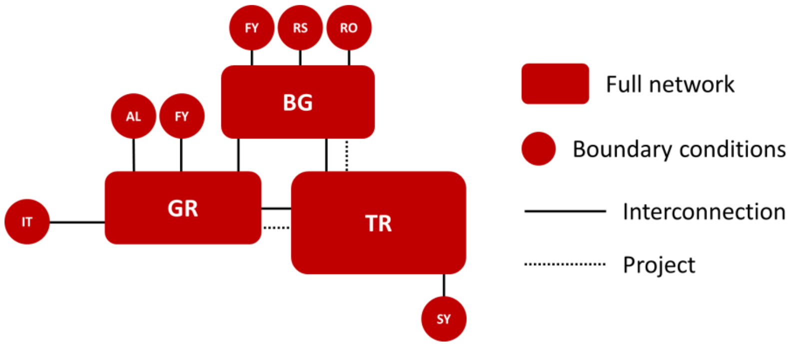

Table 1 – Participation of each of the systems involved in project GRTRBG

Concerning the representation of the systems in the model used for this project, the Greek, Turkish and Bulgarian systems have been considered as full represented by their transmission network models, while boundary systems, i.e. Albania, Italy, FYROM[1], Serbia, Romania and Syria, were 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) were distinguished, based on the distinctively different assumptions of future evolution considered in the Mediterranean project.

In data collection, the following models were provided:

- For the Greek system, a set of eight full models, corresponding with 4 scenarios and seasonality (Winter/Summer).
- For the Turkish system, a set of eight models, corresponding with 4 scenarios and seasonality (Winter/Summer).
- For the Bulgarian system a set of four models, corresponding with 4 scenarios

Full list of provided files is included in [1]. Technologies for generating units have been specified in all systems with respect to the generating technologies considered in the Mediterranean project, while all generating units of the same technology were considered with the same rank. In all models provided interconnected Areas are well identified.

Merging process consists of joining the different networks using the connecting buses defined in the next tables. First, Table 2 summarizes the interconnections between systems, which correspond with pairs of modelled systems, thus two interconnection buses must be identified, one for each of the systems in the interconnection.

Bus	**Area**	**Substation**	**Bus**	**Area**	**Substation**
XBG_TH11	Greece GR	Thessaloniki	XBG_TH11	Bulgaria BG	Blagoevgrad

[1] FYROM corresponds with 'Former Yugoslavian Republic of Macedonia'

Bus	Area	Substation	Bus	Area	Substation
XMI_NS11	Greece GR	Maritsa Iztok	XMI_NS11	Bulgaria BG	N. Santa
XNS_BA11	Greece GR	N. Santa	XNS_BA11	Turkey TR	Babaeski
XMI_HA11	Bulgaria BG	Maritsa Iztok	XMI_HA11	Turkey TR	Hamitabat
XMI_HA12	Bulgaria BG	Maritsa Iztok	XMI_HA12	Turkey TR	Hamitabat

Table 2 – Points of merging between systems in the GRTRBG project

Table 3 shows the set of interconnections that correspond with pairs formed by a modelled system and a boundary system, thus only one bus in the modelled system needs to be identified.

Bus	Area (from)	Substation	Area (to)
XZE_KA11	Greece GR	Kardia	Albania AL
XBI_MO31	Greece GR	Mourtos	Albania AL
XFL_BI11	Greece GR	Theassloniki	FYROM FY
XTH_DU11	Greece GR	Amyndeo	FYROM FY
XAR_GA1G	Greece GR	Arachthos	Italy IT
XBR_VR51	Bulgaria BG	Breznik	Serbia RS
XSO_NI11	Bulgaria BG	Sofia	Serbia RS
XSO_NI13	Bulgaria BG	Sofia	Serbia RS
XKU_ZA51	Bulgaria BG	Zadad	Serbia RS
XSO_NI12	Bulgaria BG	Sofia	Serbia RS
XSK_KP51	Bulgaria BG	Shakavitsa	FYROM FY
XCM_ST11	Bulgaria BG	Ch. Mogila	FYROM FY
XPE_SU51	Bulgaria BG	Petrich	FYROM FY
XKO_TI12	Bulgaria BG	Kozdoluy	Romania RO
XKO_TI11	Bulgaria BG	Kozdoluy	Romania RO
XVA_MG11	Bulgaria BG	Varna	Romania RO
XDO_MG11	Bulgaria BG	Dobrudzha	Romania RO
XAL_BR11	Turkey TR	Birecik	Syria SY

Table 3 – Points of merging between systems and external buses in the GRTRBG project

Finally, Table 4 presents the new interconnections associated to the GRTRBG project. The project GRTRBG considers two AC links. For the first link (Greece-Turkey), the bus XNS_BA12 is identified in both sides. For the second link (Bulgaria-Turkey), the bus XMI_HA13 identified in both sides

PROJECT	Bus	Area	Subs.	Bus	Area	Subs.	LINK
GRTRBG	XNS_BA12	Greece GR	N. Santa	XNS_BA12	Turkey TR	Babaeski	AC
GRTRBG	XMI_HA13	Bulgaria BG	Maritsa Iztok	XMI_HA13	Turkey TR	Hamitabat	AC

Table 4 – Points of merging in the Projects in the GRTRBG project

3 Snapshots definition and building process

For the project GRTRBG, a total number of nine Points in Time (PiT) have been defined [2]. Each of the PiT contains, for each of the systems considered, the active power generated, demanded and exported to the other systems. Active power production comes with a breakdown of technologies. Next table shows the power balance for each of the PiTS in GRTRBG project. In Table 5, the column 'Pextra', only non-zero for the Turkish system, represents extra energy that comes from Georgia, Iran and Iraq.

project GRBGTR PiT 1 - Power Balance [MW]

sys	PG	PD	Pextra	Pexport	GR	TR	BG	SY	AL	IT	MK	RO	RS
Greece GR	6414.1	4687.3	0.0	1726.8	0.0	1160.0	983.0	0.0	83.8	-500.0	0.0	0.0	0.0
Turkey TR	44960.3	47597.3	237.0	-2400.0	-1160.0	0.0	-1840.0	600.0	0.0	0.0	0.0	0.0	0.0
Bulgaria BG	4318.3	4071.3	0.0	247.0	-983.0	1840.0	0.0	0.0	0.0	0.0	-10.0	-300.0	-300.0

project GRBGTR PiT 2 - Power Balance [MW]

sys	PG	PD	Pextra	Pexport	GR	TR	BG	SY	AL	IT	MK	RO	RS
Greece GR	7676.3	10893.2	0.0	-3216.9	0.0	-1080.0	-1732.0	0.0	-4.9	0.0	-400.0	0.0	0.0
Turkey TR	56488.0	53321.6	249.0	3415.4	1080.0	0.0	1735.4	600.0	0.0	0.0	0.0	0.0	0.0
Bulgaria BG	5506.3	4770.2	0.0	736.1	1732.0	-1735.4	0.0	0.0	0.0	0.0	300.0	39.6	400.0

project GRBGTR PiT 3 - Power Balance [MW]

sys	PG	PD	Pextra	Pexport	GR	TR	BG	SY	AL	IT	MK	RO	RS
Greece GR	7740.0	10066.9	0.0	-2326.9	0.0	-1080.0	-96.9	0.0	-250.0	-500.0	-400.0	0.0	0.0
Turkey TR	55345.8	52939.1	249.0	2655.7	1080.0	0.0	975.7	600.0	0.0	0.0	0.0	0.0	0.0
Bulgaria BG	2828.5	4457.4	0.0	-1628.8	96.9	-975.7	0.0	0.0	0.0	0.0	-150.0	-300.0	-300.0

project GRBGTR PiT 4 - Power Balance [MW]

sys	PG	PD	Pextra	Pexport	GR	TR	BG	SY	AL	IT	MK	RO	RS
Greece GR	7242.6	6063.1	0.0	1179.5	0.0	1160.0	939.0	0.0	-156.8	-500.0	-262.7	0.0	0.0
Turkey TR	35471.1	38153.2	138.0	-2544.1	-1160.0	0.0	-1569.7	185.6	0.0	0.0	0.0	0.0	0.0
Bulgaria BG	3719.4	3838.7	0.0	-119.3	-939.0	1569.7	0.0	0.0	0.0	0.0	-150.0	-300.0	-300.0

project GRBGTR PiT 5 - Power Balance [MW]

sys	PG	PD	Pextra	Pexport	GR	TR	BG	SY	AL	IT	MK	RO	RS
Greece GR	6540.9	6234.3	0.0	306.6	0.0	1160.0	-838.6	0.0	0.0	189.8	-204.6	0.0	0.0
Turkey TR	57521.3	60146.3	225.0	-2400.0	-1160.0	0.0	-1840.0	600.0	0.0	0.0	0.0	0.0	0.0
Bulgaria BG	6734.8	4576.3	0.0	2158.5	838.6	1840.0	0.0	0.0	0.0	0.0	0.0	-300.0	-220.1

project GRBGTR PiT 6 - Power Balance [MW]

sys	PG	PD	Pextra	Pexport	GR	TR	BG	SY	AL	IT	MK	RO	RS
Greece GR	6838.8	4544.9	0.0	2294.0	0.0	1160.0	1034.0	0.0	250.0	-500.0	350.0	0.0	0.0
Turkey TR	72345.8	74723.8	-22.0	-2400.0	-1160.0	0.0	-1840.0	600.0	0.0	0.0	0.0	0.0	0.0
Bulgaria BG	4598.6	3695.8	0.0	902.8	-1034.0	1840.0	0.0	0.0	0.0	0.0	75.3	0.0	21.5

project GRBGTR PiT 7 - Power Balance [MW]

sys	PG	PD	Pextra	Pexport	GR	TR	BG	SY	AL	IT	MK	RO	RS
Greece GR	10305.3	8013.8	0.0	2291.6	0.0	1157.6	1034.0	0.0	250.0	-500.0	350.0	0.0	0.0
Turkey TR	71511.5	70695.8	238.0	1053.7	-1157.6	0.0	1611.3	600.0	0.0	0.0	0.0	0.0	0.0
Bulgaria BG	3264.5	5009.7	0.0	-1745.3	-1034.0	-1611.3	0.0	0.0	0.0	0.0	300.0	200.0	400.0

project GRBGTR PiT 8 - Power Balance [MW]

sys	PG	PD	Pextra	Pexport	GR	TR	BG	SY	AL	IT	MK	RO	RS
Greece GR	9664.6	8848.4	0.0	816.2	0.0	38.8	1034.0	0.0	119.6	-500.0	123.8	0.0	0.0
Turkey TR	70314.5	68437.6	257.0	2133.9	-38.8	0.0	1572.7	600.0	0.0	0.0	0.0	0.0	0.0
Bulgaria BG	3199.3	6441.6	0.0	-3242.3	-1034.0	-1572.7	0.0	0.0	0.0	0.0	-35.7	-300.0	-300.0

project GRBGTR PiT 9 - Power Balance [MW]

sys	PG	PD	Pextra	Pexport	GR	TR	BG	SY	AL	IT	MK	RO	RS
Greece GR	7924.2	4630.2	0.0	3294.0	0.0	1160.0	1034.0	0.0	250.0	500.0	350.0	0.0	0.0
Turkey TR	60518.0	63105.0	187.0	-2400.0	-1160.0	0.0	-1840.0	600.0	0.0	0.0	0.0	0.0	0.0
Bulgaria BG	3911.8	3855.7	0.0	56.0	-1034.0	1840.0	0.0	0.0	0.0	0.0	-150.0	-300.0	-300.0

Table 5 – Power balance for each of the PiTs defined in the GRTRBG project

4 Power flow and security analysis

This section presents the criteria agreed to run the power flow and security analysis over the different snapshots built for project GRTRBG. Details on the methodology used for the security analysis are compiled in [3].

Greece

For the Greek system, the perimeter of the security analysis was limited in the bulk transmission level. Therefore, the branches considered for the N-1 analysis but also as the monitored elements were only those at 400 kV.

Concerning rates and tolerances, from the three different values, i.e. rateA, rateB and rateC identified in the models provided, for lines rateA was considered for Winter, rateB for Summer, and rateC was not taken into consideration. For transformers, rateA was considered as unique rate, thus rateB and rateC were not taken into consideration. The tolerance considered for overload was 0% for all branches, in N and N-1 situations.

Regarding the loss of generating units, the energy lost was compensated by controlling the interconnection with FYROM.

Finally, a set of N-2 outages has been specified for the project GRTRBG:

bus FROM	bus TO	IC		bus FROM	bus TO	IC
GK_NSA11 400.00	GFILIP11 400.00	1		GKLAG11 400.00	GAMYNT11 400.00	1
GK_NSA11 400.00	GFILIP11 400.00	2		GKLAG11 400.00	GAMYNT11 400.00	2
GFILIP11 400.00	GKLAG11 400.00	1		GPTOLEM 400.00	GAMYNT11 400.00	1
GFILIP11 400.00	GKLAG11 400.00	2		GPTOLEM 400.00	GAMYNT11 400.00	2
GKYT_T11 400.00	GKLAG11 400.00	1		GKYT_T11 400.00	GAGDI12 400.00	1
GKYT_T11 400.00	GKLAG11 400.00	2		GKYT_T11 400.00	GAGDI12 400.00	2

Table 6 – N-2 outages considered for the Greek system in project GRTRBG

Turkey

For the Turkish system, the perimeter of the security analysis was limited in the bulk transmission level. Therefore, the branches considered for the N-1 analysis but also as the monitored elements were only those at 400 kV.

Concerning rates and tolerances, from the three different values, i.e. rateA, rateB and rateC identified in the models provided, for lines, rateB was considered for Summer and rateA for winter. The tolerance considered for overload was 0% for N situations, and +10% for and N-1 situations.

Regarding the loss of generating units, the energy lost was compensated internally, using the rest of Turkish generating units.

Finally, a set of N-2 outages has been specified for the project GRTRBG. This set is formed by two different clusters of lines:

'Sinop NPP' set				'Akkuyu NPP' set		
bus FROM	bus TO	IC		bus FROM	bus TO	IC
TALTIN11 400,00	TSINPN11 400,00	1		TKONYA11 400,00	TAKKYN11 400,00	1
TKURSN11 400,00	TSINPN11 400,00	1		TKRMND11 400,00	TAKKYN11 400,00	1
TKURSN11 400,00	TSINOP11 400,00	1		TSEYDS11 400,00	TAKKYN11 400,00	1
TSINOP11 400,00	TSINPN11 400,00	1		TERMEN11 400,00	TAKKYN11 400,00	1
TKSTMN11 400,00	TSINPN11 400,00	1		TMERSN11 400,00	TAKKYN11 400,00	1
TBARTN11 400,00	TKSTMN11 400,00	1		TMNVGT11 400,00	TAKKYN11 400,00	1
TBARTN11 400,00	TSINPN11 400,00	1				

Table 7 – N-2 outages considered for the Greek system in project GRTRBG

From each of the sets, N-2 considered the simultaneous outage of two lines.

Bulgaria

For the Bulgarian system, the perimeter of the security analysis was limited in the transmission levels. Therefore, the branches considered for the N-1 analysis but also as the monitored elements were only those at 220 kV or 400 kV.

Concerning rates and tolerances, from the three different values, i.e. rateA, rateB and rateC identified in the models provided, for lines and transformers, rateA was considered as unique rate, whereas rateB and rateC were not taken into consideration. The tolerance considered for overload was 0% for N and N-1 situations.

Regarding the loss of generating units, the energy lost was compensated by controlling the interconnection with FYROM, Romania and Serbia.

Finally, the set of N-2 outages was defined by considering simultaneous outage of each couple of branches with a degree of separation from the interconnections less or equal to three.

5 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.

Concerning the NTC between countries, the security analysis should consider the foreseen increase in the NTC between the countries involved as a limiting factor affecting also the need for internal reinforcements. Particularly, the NTC without the project from Greece/Bulgaria to Turkey is 1350, expected to increase with the project to 1850, while in the opposite direction it is 1250 expected to increase to 1750. The flows considered in some the PiTs examined exceed above-mentioned limits. Thus, for the foreseen NTC increase, no internal reinforcements should be required, but in case further increase of the NTC is foreseen, this would require internal reinforcements close to the border.

More specifically, focusing in each of the systems involved in the Project:

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. Balkan System is strongly interconnected and interdependent, both with Greece and Bulgaria. 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 the way future dispersed RES generation is modeled as concentrated in certain 400kV substations. This is a convention and not a realistic case.

Greece

In general terms, for the foreseen NTC increase, no internal reinforcements are needed in the Greek system. Nevertheless, any further increase of the NTC would require internal reinforcements close to the border. As realistic potential internal reinforcements, the following are considered:

- One additional double 400kV line N. Santa - Filippi, identical to the existing one
- As a second step, one additional double 400kV line Thessaloniki - Lagadas, identical to the existing one

Turkey

Reinforcements that are required to secure operation of Turkish grid with the GRTRBG interconnection project could be listed in two categories: 1 upgrade of existing OHL, and 2 addition of new OHL/addition of new connection point to existing OHL.

To increase transmission capacity of an existing 2-bundle OHL, existing route should be replaced with 3-bundle Cardinal or Pheasant OHL. Parameters of 3-bundle Cardinal and Pheasant OHLs are listed in the table below. In this study 3-bundle Cardinal OHL was used in simulation for the upgrade of existing 2-bundle OHLs.

	Rs [pu/100km]	Xs [pu/100km]	Bp [pu/100km]	rateA [MVA]	rateB [MVA]	rateC [MVA]
3-bundle Cardinal OHL	0,001306	0,016625	0,69266	1589	1334	2178
3-bundle Pheasant OHL	0,000994	0,016437	0,703719	1921	1604	2610

Table 8 – Parameters of 3-bundle Cardinal and Pheasant OHLs for the project GRTRBG

With the GRTRBG interconnection project, the 400kV Hamitabat - Babaesky OHL – 2bundle Cardinal of 25km is required to be upgraded. To reinforce Turkish grid in the vicinity of GRTRBG interconnection project's connection point, spare circuit of Verbena - Habibler OHL could be used. Verbena - Habibler OHL (400kV, double circuit 3bundle Pheasant, 160km) is being constructed as double circuit and spare circuit could be operated as Hamitabat - Alibeykoy OHL to reinforce the region.

Relevant overloads were resolved with selected reinforcements.

Next figure shows the maps of interconnections, both existing (dashed-yellow line) and planned (yellow line), and relevant internal reinforcements that were identified in the security analysis (green line).

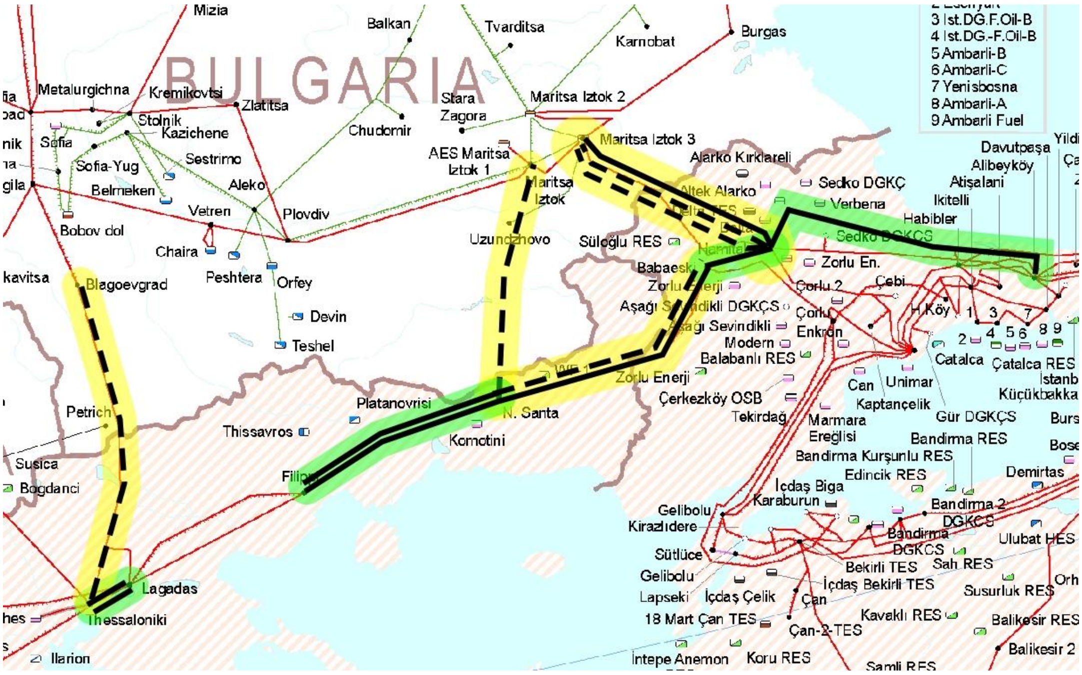

Figure 1 – Map of interconnections and reinforcements for project GRTRBG

6 Estimation of Active Power Losses

Internal losses in each country

To evaluate the performance of the new interconnection projects plus the planned reinforcements, the active power losses have been computed for 1) the snapshots built with the specified reinforcements considered, and for 2) the snapshots without interconnection projects and without reinforcements. Next tables show the active power losses summary for each of the PiTs, **Errore. L'origine riferimento non è stata trovata.** with the results for the Greek system, **Errore. L'origine riferimento non è stata trovata.** with the results for the Bulgarian system and **Errore. L'origine riferimento non è stata trovata.** with the results for the Turkish system.

	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	101.7	120.3	18.6
2	340.5	356.0	15.5
3	210.6	219.0	8.4
4	154.0	170.5	16.5
5	153.5	141.4	-12.1
6	152.7	170.4	17.6
7	157.8	225.6	67.8
8	221.6	192.8	-28.9
9	206.7	228.0	21.3

Table 10 – Comparison of the active power losses for each snapshot, with and without interconnection projects and reinforcements, for the Greek system

	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	104.8	127.7	22.9
2	159.7	146.6	-13.0
3	67.9	65.2	-2.7
4	123.9	158.9	35.0
5	107.5	112.4	4.9
6	68.1	67.3	-0.8
7	129.8	119.8	-10.0
8	159.0	151.7	-7.3
9	158.5	192.2	33.7

Table 11 – Comparison of the active power losses for each snapshot, with and without interconnection projects and reinforcements, for the Bulgarian system

	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
1	989.9	934.3	-55.7
2	990.5	1081.3	90.8
3	1042.8	1068.7	25.9
4	449.3	414.8	-34.5
5	1131.4	1090.9	-40.5
6	1591.9	1652.8	60.9
7	1612.2	1666.7	54.5
8	1894.1	1845.5	-48.6
9	1314.0	1276.3	-37.6

Table 12 – Comparison of the active power losses for each snapshot, with and without interconnection projects and reinforcements, for the Turkish system

Taking into account the time percentile (hours of the year) that each PiT represents, internal active power losses with and without the new interconnection project computed for each PiT have been converted to annual energy losses for each one of the 4 scenarios. The following table shows the annual internal delta losses estimate for each system, as well as the total annual internal losses:

Scenario	Annual Internal Losses (MWh)			
	GR	BG	TR	Total
S1	97,770	-4,764	-204,269	-111,263
S2	76,086	-3,707	-158,964	-86,586
S3	141,931	-6,915	-296,533	-161,518
S4	137,198	-6,685	-286,645	-156,132

Table 13 – Annual internal delta losses estimate for each country

Losses in the new HVAC interconnection project

Based on the hourly time series of exchange among countries provided by Market studies for each one of the 4 scenarios, with and without the new interconnection project, yearly losses on the interconnection have also been computed. Computation of losses for each hour h has been carried out for the 4 scenarios S1 to S4 and 8760 hours of estimated flows through the interconnections. The following table summarizes the values used for this estimation exercise:

link	r_l [pu]	NTC_{new} [MW]	NTC_{total} [MW]
GR-TR	0.00181	500	1160
BG-TR	0.00198	500	1840

Table 14 – Parameters for the losses estimation in the GRTRBG interconnections

Based on the above calculation the following table presents the annual losses estimate on the interconnection project for each scenario:

Scenario	Annual Losses on Interconnection (MWh)		
	GR-TR	BG-TR	Total
S1	8,821	17,973	26,794
S2	5,832	10,788	16,619
S3	20,804	60,748	81,552
S4	20,928	14,233	35,161

Table 15 – Annual losses estimate for the new GRTRBG interconnection

Both internal losses and losses on the interconnection were monetized for each scenario, taking into account the Annual Average Value of Marginal Cost, for each country, as provided by the Market Studies. Results are presented in the following table:

Scenario	Annual cost of losses (M€)									Total Interconnection (M€)	Total System (M€)	Total (M€)
	GR			BG			TR					
	Interconnection	System	Total	Interconnection	System	Total	Interconnection	System	Total			
S1	0.19	4.22	4.41	0.39	-0.21	0.18	0.58	-8.82	-8.25	1.16	-4.81	**-3.65**
S2	0.23	5.87	6.10	0.42	-0.29	0.13	0.64	-12.27	-11.63	1.28	-6.68	**-5.40**
S3	0.57	7.73	8.30	1.65	-0.38	1.28	2.22	-16.15	-13.93	4.44	-8.80	**-4.36**
S4	0.82	10.71	11.52	0.56	-0.52	0.03	1.37	-22.37	-21.00	2.74	-12.18	**-9.44**

Table 16 – Annual cost of losses estimate for the new GRTRBG interconnection

As a general remark, the project results in rather negligible losses in the interconnection, while for internal losses there is an increase in Greece, a small decrease in Bulgaria and a rather significant decrease in Turkey, resulting in a decrease of the overall losses of the project.

7 Estimation of Investment Cost

Based on the information on the interconnection project and the relevant internal reinforcements that were identified in the security analysis the total investment cost was estimated as presented in the following Table 9. As a general remark, internal reinforcements in Greece and Turkey associated with the project are relatively shallow (close to the point of connection), representing a small yet not negligible part of the investment cost (32%).

The following tables provide an estimate for the investment cost for the internal reinforcements, and the Cost Benefit Analysis (CBA) carried out based on the results of EES and TC1 activities of the Mediterranean Project. It should be noted that this is an estimation of the cost based on the best practices in the region.

P13 - GRBGTR - Investment Cost								
New Interconnections								
Description	**Type**	**Countries Involved**	**Length/number**		**Total Investment Cost**	**GTC Contribution**	**Location**	**Status**
			OHL [km]	**Cable [km]**	**M€**	**MW**		
New interconnection Greece-Turkey	AC OHL 400kV	GR - TR	130	-	65	500	N-E GR (N. Santa)to N-W TR(Babaeski)	Long-term
	OHL 400kV Circuit breaker	GR		1	1.5		N-E GR (N. Santa)	Long-term
	OHL 400kV Circuit breaker	TR		1	1.5		N-W TR(Babaeski)	Long-term
New interconnection Bulgaria-Turkey	AC OHL 400kV	BG - TR	140	-	70	500	S-E BG (Maritsa 3) to N-W TR (Hamitabat)	Long-term
	OHL 400kV Circuit breaker	BG		1	1.5		S-E BG (Maritsa 3)	Long-term
	OHL 400kV Circuit breaker	TR		1	1.5		N-W TR (Hamitabat)	Long-term
Total Cost of New Interconnections (M€ / %total)					**141**	**68%**		

Internal Reinforcements								
Description	**Type**	**Countries Involved**	**Length/number**		**Total Investment Cost**	**Capacity**	**Location**	**Status**
			OHL [km]	**Cable [km]**	**M€**	**MW / MVA**		
New OHL 400kV	Double AC OHL 400kV	GR	140	-	44	1400	N. Santa - Filippoi	Long-term
	OHL 400kV Circuit breaker	GR		2	3.0		N.Santa	Long-term
	OHL 400kV Circuit breaker	GR		2	3.0		Filippoi	Long-term
New OHL 400kV	Double AC OHL 400kV	GR	25	-	8	1400	Thessaloniki - Lagadas	Long-term
	OHL 400kV Circuit breaker	GR		2	3.0		Thessaloniki	Long-term
	OHL 400kV Circuit breaker	GR		2	3.0		Lagadas	Long-term
Replacement of conductors OHL 400kV 2-bundle Hamitabat – Babaeski	AC OHL 400kV 3-bundle	TR	25	-	3	1589-2610	N-W TR	Long-term
Operation of spare circuit of AC OHL 400kV Hamitabat – Alibeykoy	AC OHL 400kV	TR	-	-	-	1589-2610	N-W TR	Long-term
Total Cost of Internal Reinforcements (M€ / %total)					**67**	**32%**		

Total Project Investment Cost	**208**

Table 9 - Investment costs of the project GRBGTR

Assessment results for the Cluster P13 - GRBGTR														
non scenario	GTC increase direction 1 (MW)		500 (GR-TR) - 500 (BG-TR)											
	GTC increase direction 2 (MW)		500 (TR-GR) - 500 (TR-BG)											
scenario specific			MedTSO scenario											
			1			2			3			4		
			Ref. Scenario	with new project	Delta	Ref. Scenario	with new project	Delta	Ref. Scenario	with new project	Delta	Ref. Scenario	with new project	Delta
GTC / NTC (import)		GR	3462	3962	500	3462	3962	500	3462	3962	500	3462	3962	500
		BG	2090	2590	500	2090	2590	500	2090	2590	500	2090	2590	500
		TR	6200	7200	1000	6200	7200	1000	6200	7200	1000	6200	7200	1000
Interconnection Rate (%)*		GR	14.4%	16.5%	2.1%	17.8%	20.4%	2.6%	13.0%	14.9%	1.9%	13.0%	14.9%	1.9%
		BG	15.3%	18.9%	3.7%	16.4%	20.3%	3.9%	14.0%	17.3%	3.3%	17.8%	22.1%	4.3%
		TR	4.9%	5.7%	0.8%	4.9%	5.7%	0.8%	4.4%	5.1%	0.7%	4.1%	4.7%	0.7%
Benefit Indicators	B1-SEW	(M€/y)	17			37			160			71		
	B2-RES	(GWh/y)	0			0			60			300		
	B3-CO_2	(kT/y)	300			-1600			2800			-1100		
	B4 - Losses	(M€/y)	-3.7			-5.4			-12.0			-13.8		
		(GWh/y)	-84			-70			-80			-121		
	B5a-SoS Adequacy	(MWh/y)	0			0			260			200		
	B5b-SoS System Stability													
Residual Impact Indicators	S1- Environmental Impact													
	S2-Social Impact													
	S3-Other Impact													
Costs	C1-Estimated Costs	(M€)	208											

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

Rules for sign of Benefit Indicators

B1- Sew [M€/year] =	Positive when a project reduces the annual generation cost of the whole Power System
B2-RES integration [GWh/Year] =	Positive when a project reduces the amount of RES curtailment
B3-CO_2 [kt/Year] =	Negative when a project reduces the whole quantity of CO_2 emitted in one year
B4-Losses - [M€/Year] and [GWh/Yea	Negative when a project reduces the annual energy lost in the Transmission Network
B5a-SoS [MWh/Year] =	Positive when a project reduces the risk of lack of supply

Assessment	Color code
negative impact	
neutral impact	
positive impact	
Not Available/Not Available	
monetized	

Table 8 – Results of the Cost Benefit Analysis for the GRBGTR project

8 References

1	Snapshots building process	Share point
2	Guide for setting up grid models for Network studies V 5.0	Share point
3	Network Analysis and Reinforcement Assessment	Share point

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