SEERMAP

South-East Europe Electricity Roadmap

Introduction to transmission network characteristics - technical features

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Tirana, 15.12.2016

Interconnectors

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An interconnector is a structure which enables energy to flow between the transmission network

- A greater level of interconnection provides a greater diversity of potential supplies as well as facilitating competition in the open electricity market and assisting the transition to a low carbon energy sector by integrating various renewable sources.
- Increased interconnection between the TSOs can help with intermittency issues posed by renewable (mainly wind) generation and so aid and support electricity security of supply.
- More interconnectors provide a potentially attractive investment for new generation/consumer investors, because of higher security and reliability margin of the transmission networks
- Electricity market liberalization presents a combination of opportunities, challenges, and risks for interconnection project

Interconnectors

Why Interconnectors?

- Development of cross-border electricity trade in the region requires that the development of the transmission infrastructure take place through the extension and strengthening of the interconnection of power systems with the purpose of sales and exchanges of electricity.
- Some borders between the countries are already congested due to the scarce interconnection capacities and trading increase, while on the other hand some countries have not even been interconnected yet.
- The construction of the new interconnectors, have been recognized as a public good for the consumers
- Such projects has been considered in a wider context of integration of the neighbouring TSOs aimed at improving the exchange of energy and acting in favour of Energy Market development

Interconnectors

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Potential benefits of grid interconnections

- Improving reliability and pooling reserves
- Reduced investment in generating capacity
- Improving load factor and increasing load diversity
- Economies of scale in new construction
- Diversity of generation mix and supply security
- Economic exchange
- Environmental dispatch and new plant siting
- Coordination of maintenance schedules

Interconnectors

Potential benefits of grid interconnections

- Development of cross-border electricity trade in the region requires that the development of the transmission infrastructure take place through the extension and strengthening of the interconnection of power systems with the purpose of sales and exchanges of electricity.
- Some borders between the countries are already congested due to the scarce interconnection capacities and trading increase, while on the other hand some countries have not even been interconnected yet.
- The construction of the new interconnectors, have been recognized as a public good for the consumers
- Such projects has been considered in a wider context of integration of the neighbouring TSOs aimed at improving the exchange of energy and acting in favour of Energy Market development

Interconnectors

Impact of the interconnections on electricity exchanges

- Loop and parallel path flows (power flows do not necessarily follow a specified transmission path)
- Transit increase (who will cover transit costs – ITC?)!
- Losses increase/decrease!
- NTC/GTC increase!
- Market coupling!

New OHL 400 kV Romania-Bulgaria*

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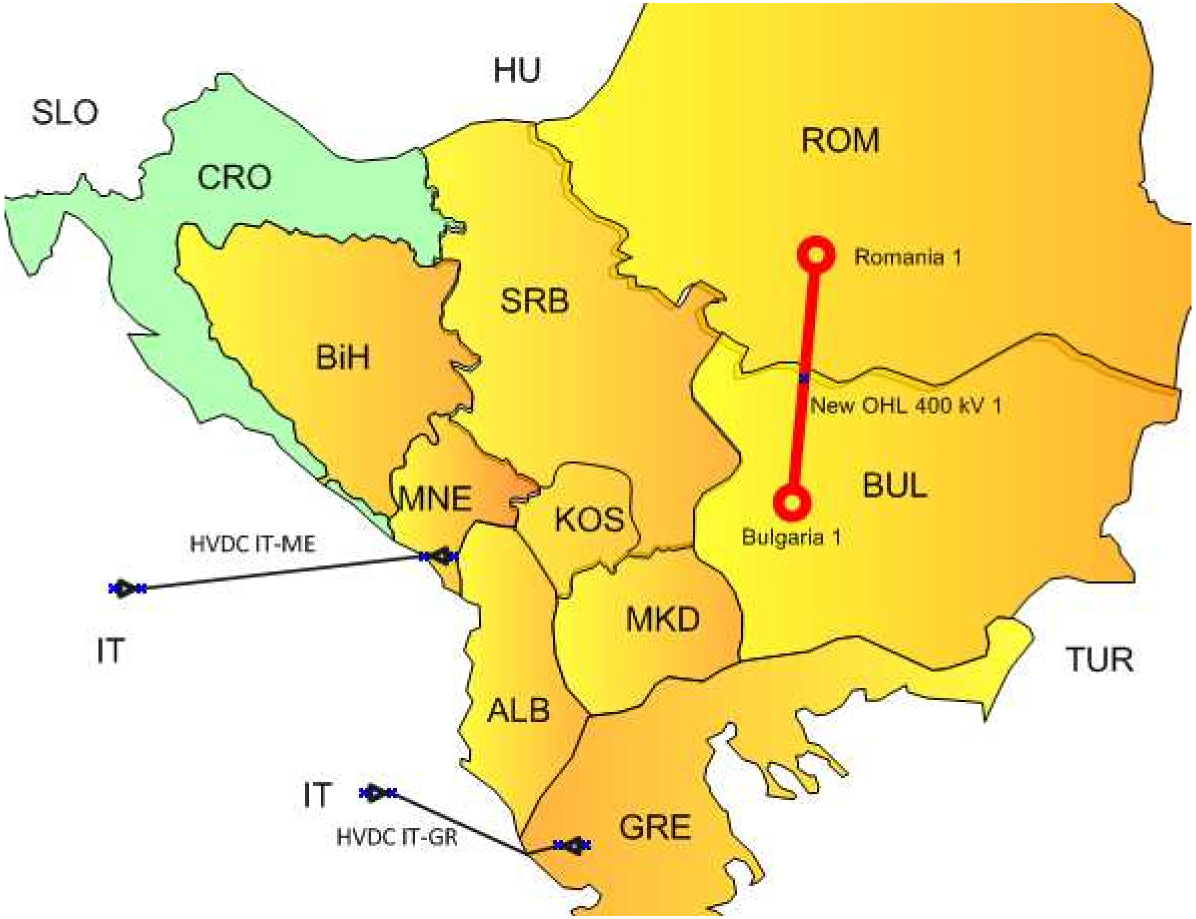

*No congestions in operational practice

Cross-border trading across the new OHL 400 kV

Benefit Categories and Required Type of Analysis

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	BENEFIT CATEGORIES:	ANALYSES	
		Network-based	Market-based
B1	Improved security of supply	**Expected Energy Not Supplied (EENS)**	
		Security analyses (n-1)	
B2	Socio-economic welfare (SEW)	**GTC calculation** Potential change of GTC (NTC) at borders with RO and BG	**Market modelling** (considering delta GTC): - market welfare - (increased) RES production - (decreased) CO2 emission
B3	RES integration		
B5	Variation in CO2 emissions		
B4	Variation in losses (energy efficiency)	**Load flow** Calculation of DLosses	
B6	Technical resilience/system safety	**Security analyses combined with maintenance (n-1-1)**	
B7	Flexibility	**Risk analysis** of dependence of Romania-Bulgaria project with other related projects	

Benefit Categories and Required Type of Analysis

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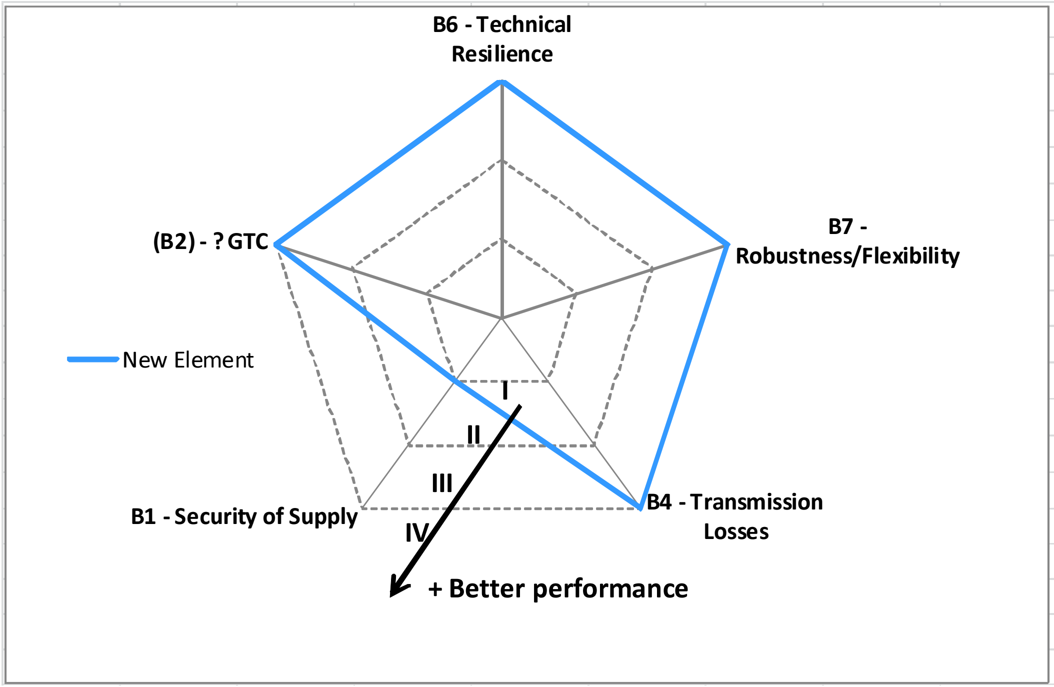
- **Technical resilience**
  - Security (n-1) analysis
  - Security (n-1) analysis with maintenance (n-1-1)
  - PV analysis
- **Robustness/Flexibility**
  - Uncertain development of transmission reinforcements
  - Contrasting power system development
- **Transmission losses**
  - Evaluation of variation in losses
- **Security of supply**
  - Evaluation of ability to provide secure supply of electricity
- **Grid Transfer Capability**
  - Effect of increasing GTC across boundary



Load Flow Analyses

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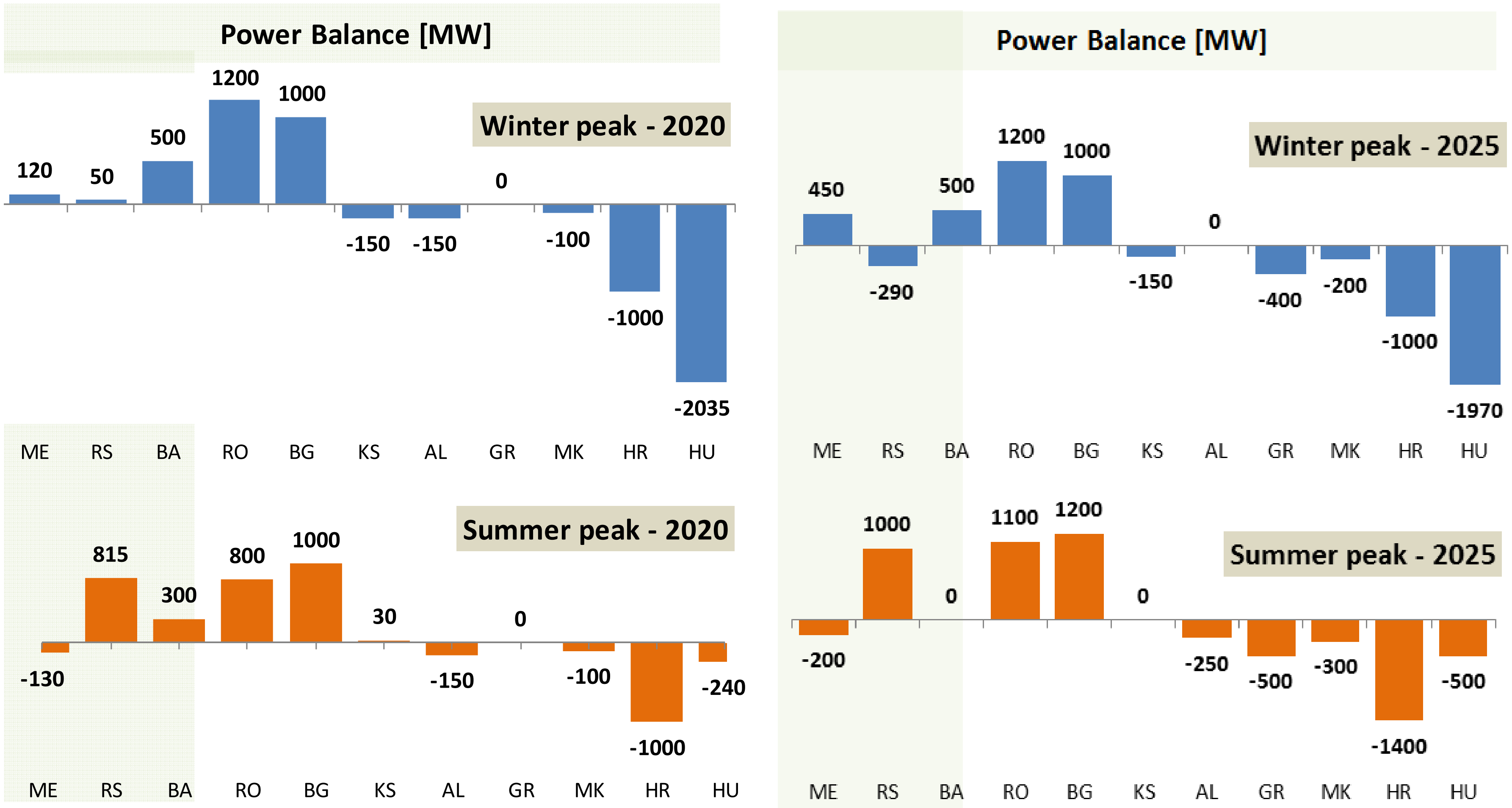
Power Balances in Network models – 2020 & 2025



Load Flow Analyses

Security of Supply – B1 (n-1) Analysis

- In Winter peak 2020 base case exchanges are
- 400 kV Portile de Fier (RO) – Djerdap (RS) for outage of 400 kV line Tantareni (RO) – Slatina (RO)

- Limiting network elements in Winter peak 2025 are:
  - 400 kV Portile de Fier (RO) – Djerdap (RS) for outage of 400 kV line Tantareni (RO) – Slatina (RO)
  - 400 kV Ch.Mogila (BG) – Stip (MK) for several outages

- In all regimes in 2020 and 2025 security (n-1) criterion is satisfied i.e. there are no overloads with the New Interconnection.

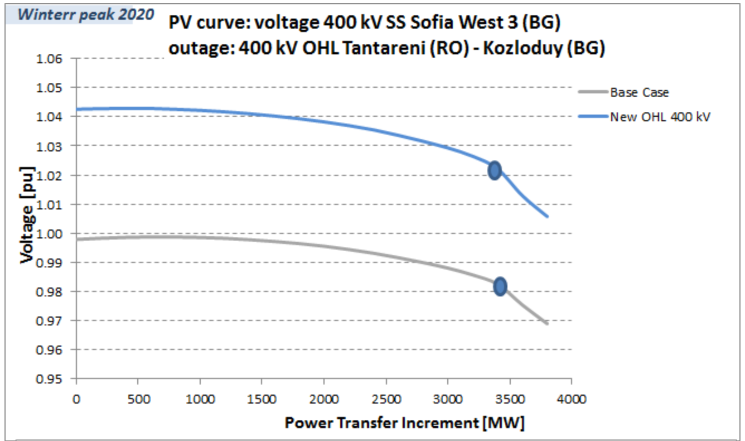
Base case "n-1" security analysis	*SCENARIO*	
	0	*1*
Summer peak 2020	?	?
Winter peak 2020	x	?
Summer peak 2025	?	?
Winter peak 2025	x	?

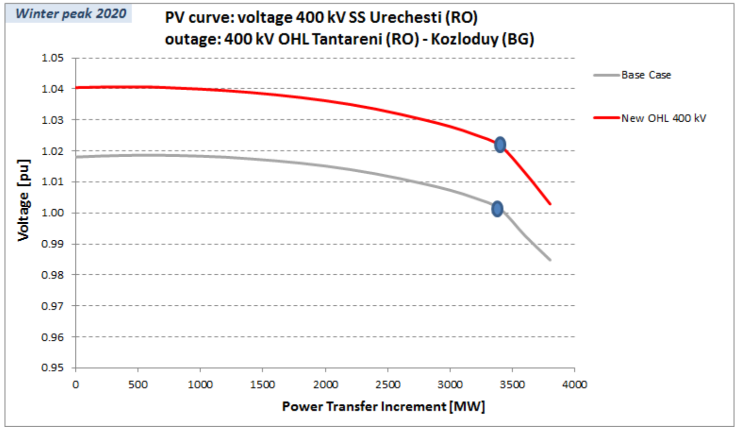
Load Flow Analyses

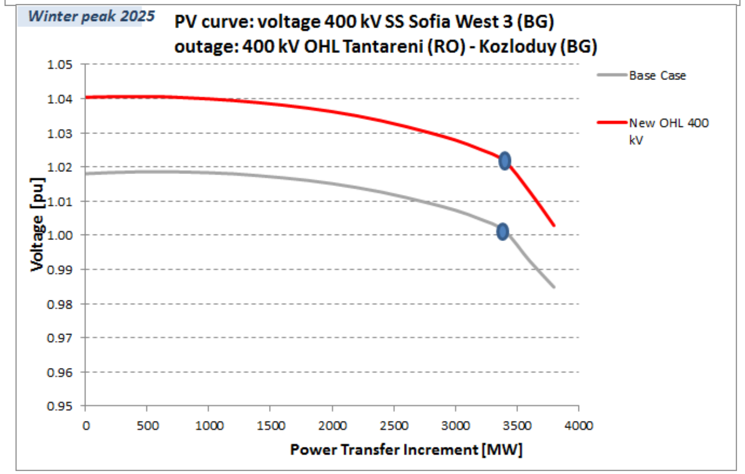
Security of Supply – B1 PV Analysis 2020/2025

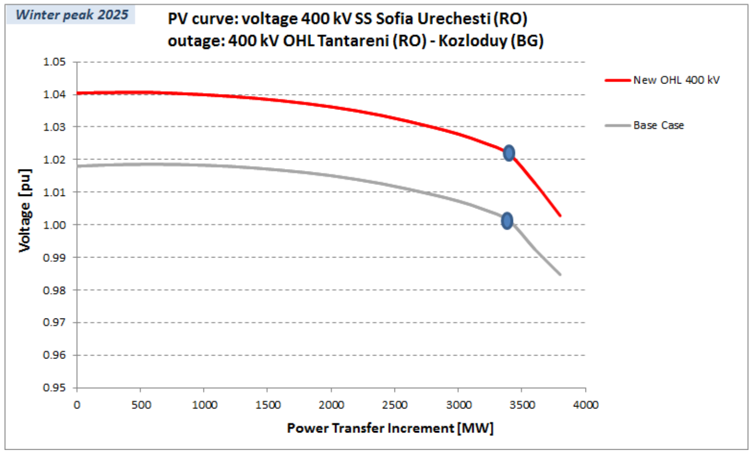
PV analysis has shown that voltage stability of observed SS was preserved for power transfers above 3500 MW for the base case and the new topology variant

New topology variant has positive effect on voltage stability









Load Flow Analyses

Security of Supply – B1 Expected Energy Not Supplied

Winter max 2020

```
                                          FREQ.  DURATION    PROB.       I.P.       E.U.E.  NO. OF <----- WORST CONTINGENCY ------>
<--  LOAD CURTAILMENTS (MW)   -->        (OC/Y)   (HOUR)     (H/Y)      (MW/Y)      (MWH/Y)  CONT.
 0.0   -- 10.0                           4.8479    21.1      102.2      27.99       599.54     20 SINGLE 462020-463665(1)
 10.0 -- 20.0                            3.1231    28.3       88.4      49.24      1383.70     16 SINGLE 462645-463715(1)
 20.0 -- 30.0                            1.5722    16.0       25.2      37.36       604.37     11 SINGLE 462000-462600(1)
 30.0 -- 40.0                            0.3674    17.3        6.4      12.50       217.43      7 SINGLE 462100-462115(1)
 40.0 -- 50.0                            0.1516    17.9        2.7       7.03       124.59      3 SINGLE 462880-462895(1)
 60.0 -- 70.0                            0.1028    17.3        1.8       6.35       110.24      2 SINGLE 462130-462175(1)
RS                                      10.1650    22.3      226.6     140.47      3039.88     59

CONTINGENCY LEGEND:
<----- CONTINGENCY LABEL ------> EVENTS
SINGLE 462020-463665(1)          OPEN LINE FROM BUS 462020 [JALEKD5     110.00] TO BUS 463665 [JBRUS 5     110.00] CKT 1
SINGLE 462645-463715(1)          OPEN LINE FROM BUS 462645 [JKRUS151    110.00] TO BUS 463715 [JKRUS35     110.00] CKT 1
SINGLE 462000-462600(1)          OPEN LINE FROM BUS 462000 [JKOZUJ5     110.00] TO BUS 462600 [JKRAG35     110.00] CKT 1
SINGLE 462100-462115(1)          OPEN LINE FROM BUS 462100 [JBGD155     110.00] TO BUS 462115 [JBGD1752    110.00] CKT 1
SINGLE 462880-462895(1)          OPEN LINE FROM BUS 462880 [JNSAD551    110.00] TO BUS 462895 [JNSAD75     110.00] CKT 1
SINGLE 462130-462175(1)          OPEN LINE FROM BUS 462130 [JBGD2 51    110.00] TO BUS 462175 [JBGD325     110.00] CKT 1
```

Winter max 2025

```
                                          FREQ.  DURATION    PROB.       I.P.       E.U.E.  NO. OF <----- WORST CONTINGENCY ------>
<--  LOAD CURTAILMENTS (MW)   -->        (OC/Y)   (HOUR)     (H/Y)      (MW/Y)      (MWH/Y)  CONT.
 0.0   -- 10.0                           4.8479    21.1      102.2      27.99       599.54     20 SINGLE 462020-463665(1)
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RS                                      10.1650    22.3      226.6     140.47      3039.88     59

CONTINGENCY LEGEND:
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```

Load Flow Analyses

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Security of Supply – B1 S Expected Energy Not Supplied

- *EENS is calculated for the topology scenarios defined to evaluate variations between calculated EENS value for the respective scenario and the level of EENS in the base case topology*

$$\Delta EENS_i = EENS_i - \Delta EENS_0$$

$EENS_i$ – Expected Energy Not Supplied for the topology variant *i*

$EENS_0$ – Expected Energy Not Supplied for the base case topology

- Results showed that variation in EENS compared to base case topology is close to zero for all scenarios of the New Interconnections (0.3 GWh/year in BG; 0.6 GWh/year in RO)
- Loss of load or load curtailments due to overloads happen in 110 kV network and New Interconnection does not influence problematic parts of the 110 kV network and does not improve Security of supply in any of the analyzed countries

Load Flow Analyses

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Variation of Transmission Losses – B4

- Network losses are presented on yearly level (GWh) based on losses in MW calculated for:
  - 2 peak regimes
  - equivalent losses duration time of the respective loads in these regimes

$$W_{loss} = W_{loss}^{Wmax} + W_{loss}^{Smax}$$

$$W_{loss}^{i} = \frac{P_{loss}^{i}(MW) * T_{eq}^{i}(h)}{1000} [GWh] \quad i = Wmax, Smax$$

P_{loss}^{i} - Active power losses in *MW* in specific regime *i*

T_{eq}^{i} - Equivalent losses duration time in *hours* in regime *i*

- Equivalent duration time in Winter max and Summer max regime is calculated based on the hourly load values from 2014 for the countries observed.

- Assumption is that Winter maximum load represents six months from October to March, Summer load represents six months from April to September – maximum load: hours 8-24 and minimum load: hours 1-7.

Load Flow Analyses

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Variation of Transmission Losses – B4

Calculation parameters	2020																	
	Serbia		Macedonia		Montenegro		Albania		Bosnia&Herzegovina		Bulgaria		Greece		Kosovo		Romania	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Equivalent duration time of maximum losses [h]	2841	2964	2965	2824	3133	2171	2961	2375	2273	2371	3262	3107	3446	2388	2073	1663	3701	2969
Variation of transmission losses [MW]																		
W/O NEW OHL	188.9	121.8	35.6	19.9	32.3	36.1	37.9	30.3	77.5	63	193.9	121.6	164.9	223.1	27.9	16.6	338.6	232.9
WITH NEW OHL	187.0	120.6	34.9	19.5	32.3	36.1	37.9	30.3	77.5	63	197.778	124.032	161.6	220.9	27.3	16.3	331.8	228.2
ΔW/O	-1.9	-1.2	-0.7	-0.4	0.0	0.0	0.0	0.0	0.0	0.0	3.9	2.4	-3.3	-2.2	-0.6	-0.3	-6.8	-4.7
Variation of yearly transmission losses [GWh]																		
ΔScenario	-9.0		-3.2		0.0		0.0		0.0		20.2		-16.7		-1.7		-38.9	

Calculation parameters	2025																	
	Serbia		Macedonia		Montenegro		Albania		Bosnia&Herzegovina		Bulgaria		Greece		Kosovo		Romania	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Equivalent duration time of maximum losses [h]	2841	2964	2965	2824	3133	2171	2961	2375	2273	2371	3262	3107	3446	2388	2073	1663	3701	2969
Variation of transmission losses [MW]																		
W/O NEW OHL	182.3	121.4	28.9	18.6	33.7	37.1	38.4	33.1	79.8	65.9	196.3	109.7	195.4	139.4	31.7	20.2	351.4	253.6
WITH NEW OHL	180.5	120.2	28.3	18.2	33.5	36.9	38.2	32.8	79.5	65.7	200.226	111.894	191.5	138.0	31.1	19.8	344.4	248.5
ΔW/O	-1.8	-1.2	-0.6	-0.4	-0.2	-0.2	-0.2	-0.3	-0.3	-0.2	3.9	2.2	-3.9	-1.4	-0.6	-0.4	-7.0	-5.1
Variation of yearly transmission losses [GWh]																		
ΔScenario	-8.8		-2.8		-1.1		-1.3		-1.2		19.6		-16.8		-2.0		-41.1	

Load Flow Analyses

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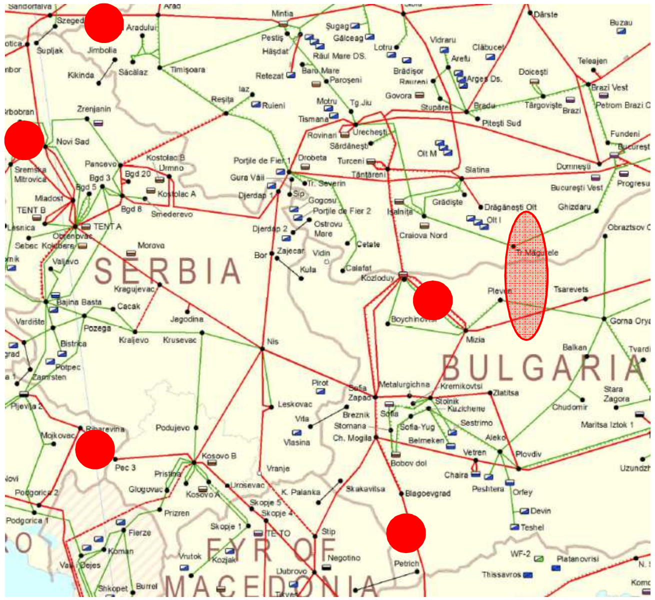
Technical Resilience/System Safety – B6

- Security (n-1) assessment combined with maintenance (n-1-1) – project's ability to deal with the operation of future transmission systems
- **TWO** maintenance lists of transmission lines are defined based on past experience



Lines in maintenance

New Interconnections

- **Maintenance 1**
  - -400 kV Ernestinovo (HR) – Sremska Mitrovica (RS)
  - -400 kV Kozlodyu (BG) – Tantareni (RO) –double OHL
  - -400 kV Ribarevine (ME) – Pec (KS)
  - -400 kV Blagoevgrad (BG) – Solun (GR)
  - -400 kV Arad (RO) – Sandorfalva (HU)

Load Flow Analyses

Technical Resilience/System Safety – B6

Lines in maintenance

New Interconnections

• **Maintenance 2**
- -400 kV Nis 2 (RS) – Bor (KS)
- -400 kV Zemlak (GR) – Elbasan (AL)
- -400 kV Stip – Dubrovo (MK)

Load Flow Analyses

Technical Resilience/System Safety – B6

- **Maintenance 1**
  - -400 kV Ernestinovo (HR) – Sremska Mitrovica (RS)
  - -400 kV Kozlodyu (BG) – Tantareni (RO) –double OHL
  - -400 kV Ribarevine (ME) – Pec (KS)
  - -400 kV Blagoevgrad (BG) – Solun (GR)
  - -400 kV Arad (RO) – Sandorfalva (HU)

- **Maintenance 2**
  - -400 kV Nis 2 (RS) – Bor (KS)
  - -400 kV Zemlak (GR) – Elbasan (AL)
  - -400 kV Stip – Dubrovo (MK)

	MAINTENANCE 1		*SCENARIO*	
	Loaded >100%	...for the outage of:	*0*	*New OHL*
2020	400 kV OHL Djerdap (RS) - Bor (RS)	400 kV resica (RO) - Portile de Fier (RO)	x	√
2025	400 kV OHL Djerdap (RS) - Bor (RS)	400 kV resica (RO) - Portile de Fier (RO)	x	√

	MAINTENANCE 2		*SCENARIO*	
	Loaded >100%	...for the outage of:	*0*	*1*
2025			√	√
2030			√	√

Load Flow Analyses

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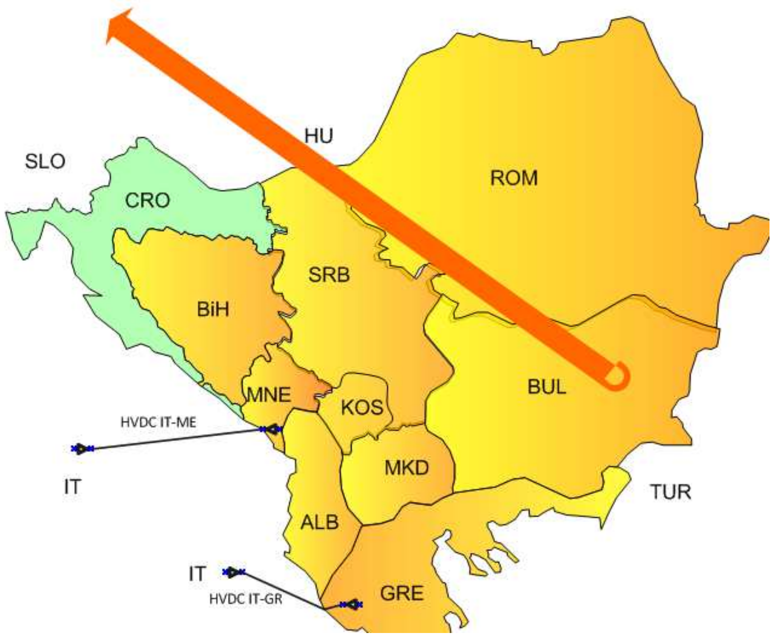
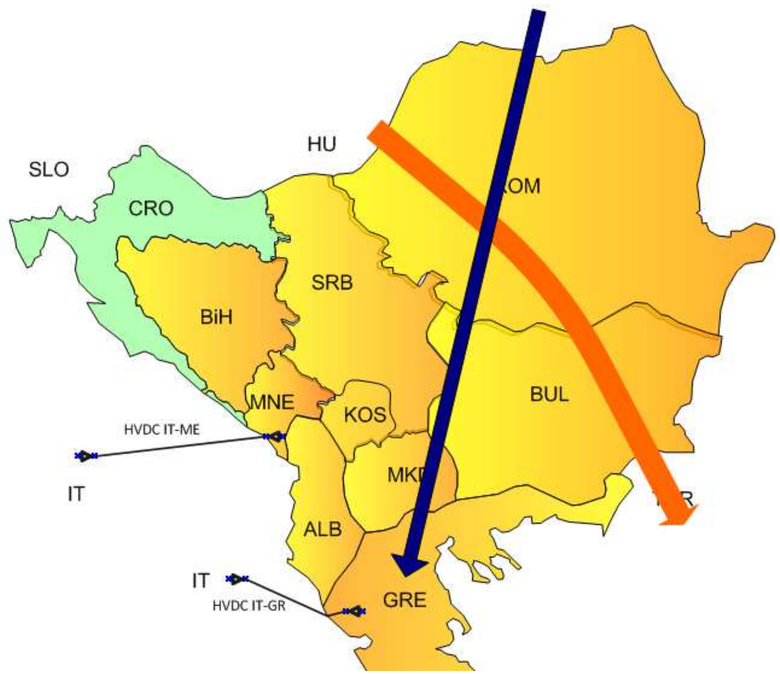
Robustness/Flexibility – B7

Additional exchanges WinMax



Additional exchanges SumMax



Load Flow Analyses

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Robustness/Flexibility – B7

"n-1" security analysis - Transmission Development Delays -	SCENARIO WINTER/SUMMER 2020	
	0	1
400kV Bitola (MK) - Elbasan (AL)	√/√	√/√
400kV Pancevo (RS) - Resica (RO) & 400kV Bitola (MK) - Elbasan (AL)	√/√	√/√

"n-1" security analysis - Transmission Development Delays -	SCENARIO WINTER/SUMMER 2025	
	0	1
400kV Kragujevac - Kraljevo (RS)	√/√	√/√
400kV SS Maritsa East 1 (BG) -SS N.Santa (GR)	√/√	√/√

The new project is not affected by the different power exchanges Variants, or delay in construction, because there are no cross border trading that significantly affects this line.

<u>Consequently, the project is flexible and retains its benefits even for the altered Variants of cross-border power exchanges</u>

Load Flow Analyses

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NTC/GTC Calculation

Final achievements

Net Transfer Capacity (NTC) calculated in composite way, between:

- Romania + Ukraine ⇒ Bulgaria
- Bulgaria + Turkey ⇒ Romania

GTC (as a physical correspondent to the commercial NTC value), also recorded at the borders;

ENTSO-E: **A project with a GTC increase of at least 500 MW compared to the situation without commissioning of the project is deemed to have a significant cross-border impact.**

NTCs have been compared for:

- Base Case
- VS.
- Variant “With New OHL (400 kV RO-BG)

Load Flow Analyses

NTC Calculation

BASE CASE

2020 SUMER MAX					
BORDER DIRECTION	BCE	DEmax	TTC	TRM	NTC
RO -> BG	500	400	900	100	**800**
BG -> RO	-500	1250	750	100	**650**

2020 WINTER MAX					
BORDER DIRECTION	BCE	DEmax	TTC	TRM	NTC
RO -> BG	300	700	1000	100	**900**
BG -> RO	-300	850	550	100	**450**

2025 SUMER MAX					
BORDER DIRECTION	BCE	DEmax	TTC	TRM	NTC
RO -> BG	700	800	1500	100	**1400**
BG -> RO	-700	1650	950	100	**850**

2025 WINTER MAX					
BORDER DIRECTION	BCE	DEmax	TTC	TRM	NTC
RO -> BG	400	1200	1600	100	**1500**
BG -> RO	-400	1250	850	100	**750**

WITH NEW OHL

2020 SUMER MAX					
BORDER DIRECTION	BCE	DEmax	TTC	TRM	NTC
RO -> BG	500	900	1400	100	**1300**
BG -> RO	-500	1500	1000	100	**900**

2020 WINTER MAX					
BORDER DIRECTION	BCE	DEmax	TTC	TRM	NTC
RO -> BG	300	1450	1750	100	**1650**
BG -> RO	-300	1150	850	100	**750**

2025 SUMER MAX					
BORDER DIRECTION	BCE	DEmax	TTC	TRM	NTC
RO -> BG	700	1450	2150	100	**2050**
BG -> RO	-700	2250	1550	100	**1450**

2025 WINTER MAX					
BORDER DIRECTION	BCE	DEmax	TTC	TRM	NTC
RO -> BG	400	1950	2350	100	**2250**
BG -> RO	-400	1700	1300	100	**1200**

CONCLUSIONS

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	ENTSO-E Benefits
B1 Improved Security of Supply	• No significant influence
B3. RES Integration	• There is no impact on RES generation constraints from the new interconnection since no RES spillages are observed
B4. Variation in Losses (GWh)	• Scenario produces the largest overall decrease in transmission system losses
B6. Technical Resilience/System Safety	• The project satisfies all recommended security criteria
B7. Flexibility	• The scenario shows more flexibility and robustness in respect of possible power exchanges in the SEE region
Grid Transfer Capability (GTC)	• The project provides significant increases of potential exchange in both the South to North and North to South-East directions.

Contact Details

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