Deliverable 2.1.2

Detailed Project Description

11 - EYJO Egypt - Jordan

EC DEVCO - GRANT CONTRACT: ENPI/2014/347-006

"Mediterranean Project"

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

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1 Introduction

The present document contains the studies on project EYJO, in the context of the Mediterranean Master Plan of Interconnections. Project EYJO consists of new interconnection between Jordan and Egypt (+550 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

Jordan and Egypt are electrically interconnected since 1998 via a 13 km 400 kV submarine cable across the Gulf of Aqaba to Taba with an exchange capability of 550 MW. Egypt and Jordan are part of the 8th countries interconnection which consists in addition to them Syria, Lebanon, Turkey, Iraq, Palestine, and Libya. The new project is relating to add a new interconnection which will lead to double the current capacity between Egypt-Jordan to be 1100 MW.

The main driver of the project is to further increase the interconnection capacity between Egypt, and Jordan to reach 1100 MW. This will allow increasing the integration of Renewable Energy generation, grid stabilization helping both countries to meet their load demand which will have the effect on postponing the investments in both generation and transmission. Main Drivers for snapshots selection:

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

Project details

Description	***Substation (from)***	***Substation (to)***	***GTC contribution (MW)***	***Present status***	***Expected commissioning date***	***Evolution***	***Evolution driver***
New interconnection between Egypt and Jordan (AC)	Jordan (JO) Aqaba	Egypt (EY) Taba	550	Long-term project	*n.d.*	*n.d.*	Double the transfer capacity between Egypt and Jordan

The system defined for project EYJO is described in the table and figure below.

Full models	**Boundaries**
Egypt EY	Syria SY
Jordan JO	Libya LY
	Palestine PA

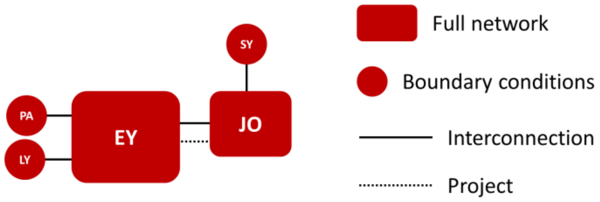

Table 1 – Participation of each of the systems involved in project EYJO

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

In the snapshots definition, 4 scenarios (S1, S2, S3 and S4) and seasonality (Winter/Summer) were distinguished, based on the distinctively different assumptions of future evolution considered in the Mediterranean project.

In data collection, seven models in PSS/E v33 have been provided by the Jordanian TSO, the first three including full representation of the Jordanian network and equivalents for the Egyptian and Syrian systems, while in the last four the Syrian is represented with a single bus. Full list of provided files is included in [1].

Technologies for generating units have been specified in the Jordanian system with respect to the generating technologies considered in the Mediterranean project, while all Egyptian and Syrian generating units have been considered of the same technology and rank.

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**
TABACBL	Egypt EY	Taba	AQBACBL	Jordan JO	Aqaba

Table 2 – Points of merging between systems in the EYJO 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)**
HASSAN_IND	Jordan JO	Hasseimya	Syria SY

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

Finally, Table 4 presents the new interconnection associated to the EYJO project. More specifically, the project EYJO consider doubling the links TABA400-TABACBL-AQBACBL-ATP400.

PROJECT	**Bus**	**Area**	**Subs.**	**Bus**	**Area**	**Subs.**	**LINK**
EYJO	TABACBL	Egypt EY	Taba	AQBACBL	Jordan JO	Aqaba	AC

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

For energy interchanges between Egypt and Libya and Palestine, they have been shared among all the network using extra loads.

3 Snapshots definition and building process

For the project EYJO, a total number of seven Points in Time (PiT) have been defined (PiT1 and PiT5 were discarded) [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 EYJO project. Power mismatch identified in some of the PiTs were properly corrected before the snapshots building.

project EYJO PiT 2 - Power Balance [MW]

sys	PG	PD	Pexport	EY	JO	SY	LY	PA
Egypt EY	36096.4	34395.2	1701.3	0.0	1100.0	0.0	550.0	51.3
Jordan JO	4692.7	5012.3	-319.6	-1100.0	0.0	780.4	0.0	0.0

project EYJO PiT 3 - Power Balance [MW]

sys	PG	PD	Pexport	EY	JO	SY	LY	PA
Egypt EY	48207.8	49919.8	-1712.0	0.0	-1100.0	0.0	-550.0	-62.0
Jordan JO	6622.6	4722.7	1900.0	1100.0	0.0	800.0	0.0	0.0

project EYJO PiT 4 - Power Balance [MW]

sys	PG	PD	Pexport	EY	JO	SY	LY	PA
Egypt EY	30850.3	29140.3	1710.0	0.0	1100.0	0.0	550.0	60.0
Jordan JO	3472.6	5372.5	-1900.0	-1100.0	0.0	-800.0	0.0	0.0

project EYJO PiT 6 - Power Balance [MW]

sys	PG	PD	Pexport	EY	JO	SY	LY	PA
Egypt EY	58156.6	59797.5	-1641.0	0.0	-1100.0	0.0	-550.0	9.0
Jordan JO	9326.1	7426.1	1900.0	1100.0	0.0	800.0	0.0	0.0

project EYJO PiT 7 - Power Balance [MW]

sys	PG	PD	Pexport	EY	JO	SY	LY	PA
Egypt EY	41409.0	39736.2	1672.8	0.0	1100.0	0.0	550.0	22.8
Jordan JO	5964.9	6265.0	-300.0	-1100.0	0.0	800.0	0.0	0.0

project EYJO PiT 8 - Power Balance [MW]

sys	PG	PD	Pexport	EY	JO	SY	LY	PA
Egypt EY	39766.6	38088.1	1678.5	0.0	1100.0	0.0	550.0	28.5
Jordan JO	4566.6	4866.6	-300.0	-1100.0	0.0	800.0	0.0	0.0

project EYJO PiT 9 - Power Balance [MW]

sys	PG	PD	Pexport	EY	JO	SY	LY	PA
Egypt EY	30381.6	28667.6	1714.0	0.0	1100.0	0.0	550.0	64.0
Jordan JO	3886.2	4211.8	-325.6	-1100.0	0.0	774.4	0.0	0.0

Table 5 – Power balance for each of the PiTS defined in the EYJO 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 EYJO. Details on the methodology used for the security analysis are compiled in [3].

Egypt

For the Egyptian 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 400 kV and 500 kV.

Concerning rates and tolerances, from the three different values, i.e. rateA, rateB and rateC identified in the models provided, only rateA was considered for all snapshots for lines and transformers, while 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 internally, using the rest of active local (Egyptian) generating units.

Finally, no N-2 situations have been considered for Egypt.

Jordan

For the Jordanian system, the perimeter of the security analysis was limited in the transmission levels. Therefore, the branches considered for the N-1 analysis were only those at 400 kV, whereas the monitored elements include branches at 132 kV and 400 kV.

Concerning rates and tolerances, from the three different values, i.e. rateA, rateB and rateC identified in the models provided, only rateB was considered for all snapshots for lines and transformers, while rateA and rateC were not taken into consideration. The tolerance considered for overload was -10% for all branches in N, and 0% in N-1 situations.

Regarding the loss of generating units, the 10% of the energy lost was compensated from local (Jordanian) generating units, and the 90% from Egypt.

Finally, no N-2 situations have been considered for Jordan.

5 Assessment of reinforcements

Jordan

Considering possible overloads in the path of the interconnection, a new reinforcement was analyzed. The link MAAN - AQABA, actually a 400 kV double circuit, is going to be doubled, i.e. four circuits between MAAN and AQABA.

Egypt

Considering possible overloads in the path of the interconnection, a new reinforcement was analyzed. The reinforcement consists of doubling the 500 kV circuit between O-MOUSA - TABA and the 500/400 kV transformer at TABA substation.

Relevant overloads were resolved with selected reinforcements. Next figure shows the map of interconnections, both existing (dashed-yellow line) and projected (yellow line) and relevant internal reinforcements that were identified in the security analysis (green line).

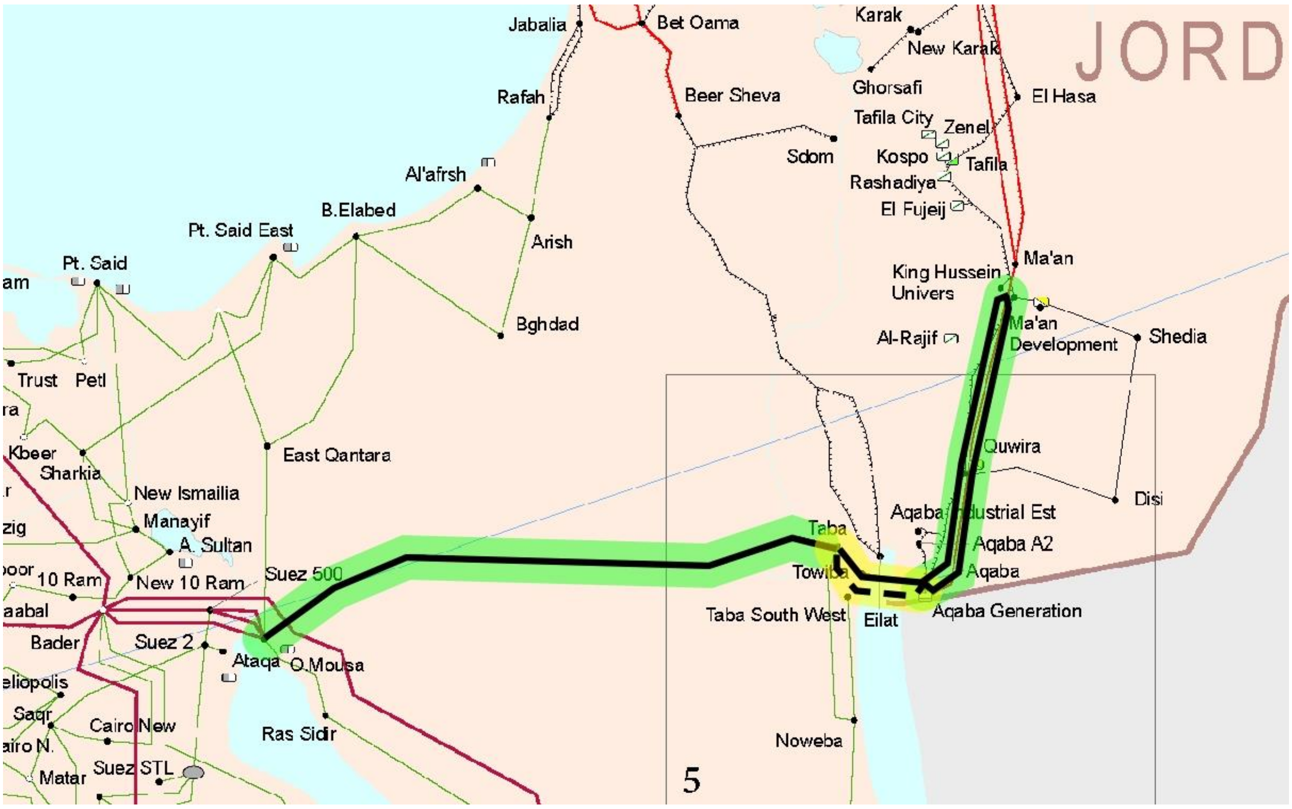

Figure 1 – Map of interconnections and reinforcements for project EYJO

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 Egyptian system and **Errore. L'origine riferimento non è stata trovata.** with the results for the Jordanian system.

	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
2	429.4	450.4	21.0
3	805.7	798.3	-7.4
4	316.8	336.5	19.7
6	1144.9	1132.3	-12.5
7	549.5	576.8	27.3
8	513.9	538.3	24.4
9	304.6	325.6	21.0

Table 6 – Comparison of the active power losses for each snapshot, with and without interconnection projects and reinforcements, for the Egyptian system

	Power losses [MW]		
PiT	Without proj&reinf	With proj&reinf	Difference (W-WO)
2	118.4	123.6	5.2
3	86.7	87.5	0.9
4	125.9	122.8	-3.2
6	211.3	211.5	0.2
7	221.5	215.0	-6.4
8	137.5	135.4	-2.1
9	142.7	141.0	-1.7

Table 7 – Comparison of the active power losses for each snapshot, with and without interconnection projects and reinforcements, for the Jordanian 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)		
	EY	JO	Total
S1	87,679	-7,074	80,606
S2	110,763	-8,936	101,827
S3	92,921	-7,497	85,424
S4	106,926	-8,626	98,300

Table 8 – 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]
EY-JO	0.000630	550	1100

Table 9 – Parameters for the losses estimation in the EYJO interconnection

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)
	EY-JO
S1	7,073
S2	8,641
S3	6,844
S4	8,230

Table 10 – Annual losses estimate for the new EYJO 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 the countries involved, 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€)
	EY			JO					
	Interconnection	System	Total	Interconnection	System	Total			
S1	0.29	7.18	7.47	0.29	-0.58	-0.29	0.58	6.60	**7.18**
S2	0.38	9.81	10.20	0.38	-0.79	-0.41	0.77	9.02	**9.79**
S3	0.28	7.68	7.96	0.28	-0.62	-0.34	0.57	7.06	**7.63**
S4	0.36	9.39	9.75	0.36	-0.76	-0.40	0.72	8.64	**9.36**

Table 110 – Annual cost of losses estimate for the new EYJO interconnection

As a general remark, the project results in rather negligible losses in the interconnection, while for internal losses there is a small decrease in Jordan and an increase in Egypt, resulting in a small increase 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 tables. As a general remark, internal reinforcements associated with the project are rather deep both in Jordan and Egypt, compared to the length of the interconnection, representing the most important part of the investment cost (~70%).

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.

P11 - EYJO - 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 Jordan - Egypt	AC OHL 400kV in Jordan	JO	9	-	5	550	S JO	Long-term
	OHL 400kV Circuit breaker	JO		1	1.5		S JO	Long-term
	AC Submarine 400kV	JO-EY	-	12	46		S JO – E EY	Long-term
	AC OHL 400kV in Egypt	EY	18	-	9		E EY	Long-term
	OHL 400kV Circuit breaker	EY		1	1.5		E EY	Long-term
Total Cost of New Interconnections (M€ / %total)					**62**	**31%**		
Internal Reinforcements								
Description	**Type**	**Countries Involved**	**Length/number**		**Total Investment Cost**	**Capacity**	**Location**	**Status**
			OHL [km]	**Cable [km]**	**M€**	**MW / MVA**		
New AC OHL 400kV Maan - Aqaba	Double AC OHL 400kV	JO	150	-	45	1000	S JO	Long-term
	400 kV Bay AIS	JO		1	3		S JO (Maan)	Long-term
	400 kV Bay GIS	JO		1	3.5		S JO (Aqaba)	Long-term
New AC OHL 400kV O-Mousa - Taba	Double AC OHL 500kV	EY	250	-	75	1040	E -W EY	Long-term
	400 kV Bay AIS	EY		1	3		E -W EY (O-Mousa)	Long-term
	400 kV Bay AIS	EY		1	3		E -W EY (Taba)	Long-term
New 500/400 kV transformer at Taba	500/400 kV transformer	EY		1	4		E -W EY (Taba)	Long-term
Total Cost of Internal Reinforcements (M€ / %total)					**136**	**69%**		
Total Project Investment Cost					**198**			

Table 12 – Investment costs of the project EYJO

Assessment results for the Cluster P11 - EYJO															
non scenario	GTC increase direction 1 (MW)			550											
	GTC increase direction 2 (MW)			550											
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)			EY	1250	1800	550	1250	1800	550	1250	1800	550	1250	1800	550
			JO	1350	1900	550	1350	1900	550	1350	1900	550	1350	1900	550
Interconnection Rate (%)*			EY	1.4%	2.1%	0.6%	1.4%	2.1%	0.6%	1.3%	1.9%	0.6%	1.4%	2.0%	0.6%
			JO	12.6%	17.8%	5.1%	11.6%	16.3%	4.7%	12.4%	17.5%	5.1%	11.0%	15.5%	4.5%
Benefit Indicators	B1-SEW		(M€/y)	25			39			35			47		
	B2-RES		(GWh/y)	0			0			0			0		
	B3-CO_2		(kT/y)	-150			-300			-200			-450		
	B4 - Losses		(M€/y)	7.3			9.9			7.5			9.4		
			(GWh/y)	88			110			92			107		
	B5a-SoS Adequacy		(MWh/y)	0			0			60			20		
	B5b-SoS System Stability														
Residual Impact Indicators	S1- Environmental Impact														
	S2-Social Impact														
	S3-Other Impact														
Costs	C1-Estimated Costs		(M€)	198											

* 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	(red)
neutral impact	(light pink)
positive impact	(green)
Not Available/Not Available	(grey)
monetized	(yellow)

Table 13 – Results of the Cost Benefit Analysis for the EYJO 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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