# ΔΙΑΚΗΡΥΞΗ ΔΑΠΜ[1]- 41719

## ΕΚΠΟΝΗΣΗ ΜΕΛΕΤΗΣ ΣΚΟΠΙΜΟΤΗΤΑΣ, ΜΕΛΕΤΗΣ ΚΟΣΤΟΥΣ ΟΦΕΛΟΥΣ ΚΑΙ ΠΑΡΟΧΗ ΥΠΟΣΤΗΡΙΚΤΙΚΩΝ ΥΠΗΡΕΣΙΩΝ ΓΙΑ ΤΟ ΕΡΓΟ «ΦΑΣΗ ΙΙ: ΔΙΑΣΥΝΔΕΣΗ ΣΡ ΟΝΟΜΑΣΤΙΚΗΣ ΙΚΑΝΟΤΗΤΑΣ 2x350 MW ΚΡΗΤΗ-ΑΤΤΙΚΗ»

## ΤΕΥΧΟΣ 8

## ΤΕΧΝΙΚΟ ΜΕΡΟΣ

[1] ΔΑΠΜ:Διεύθυνση Αποθηκών, Προμηθειών & Μεταφορών

# Call for Tender ΔΑΠΜ[2]- 41719

## “Carrying out of Feasibility Study, Cost Benefit Analysis (CBA) and provision of Supporting Services for the project “Phase II: DC interconnection, 2×350MW capability, Crete – Attica”

## ISSUE 8

## TECHNICAL DESCRIPTION

[2] ΔΑΠΜ: Purchasing & Logistics Department of IPTO

## Terms of Reference

## Technical Description

For the assignment:

### *"Carrying out of Feasibility Study, Cost Benefit Analysis (CBA) and provision of Supporting Services for the project "Phase II: DC interconnection, 2×350MW capability, Crete – Attica"*

### 1. Introduction

The project "Phase II: DC interconnection, 2×350MW capability, Crete – Attica" constitutes the Phase II of the wider project of interconnection of Crete with the Mainland System (HETS). The Phase I is the "150 kV AC INTERCONNECTION 2x200 MVA ( ~ 2x140 MW) CRETE-PELOPONNESE".

The project is the cluster 14.26 in the TYNDP 2017-2026[3] approved by RAE's Decision 280/2016 (Official Gazette 2534, 17-8-2016) and also in the current TYNDP 2018-2027 recently submitted to RAE for approval . In Annex I the extract of the new TYNDP 2018-2027 for the project is provided, while in Annex II the most recent configuration is presented.

The project "Phase II: DC interconnection, 2×350MW capability, Crete – Attica" is considered as "Major Project" in the framework of EU funds (Article 100 of Regulation (EU) No 1303/2013). Its total eligible cost amounts to approximately € 720 million[4] (excluding contingencies and VAT), exceeding the € 75 million financial threshold set by the above regulation and in conformity with the national thematic axis.

IPTO S.A. (the owner and operator of the Hellenic Transmission System), the project's promoter, aiming to obtain co-financing in the framework of EU Funds, is obliged to prepare and submit the information required, referred to in Article 101 (information necessary for the approval of a major project) of Regulation (EU) No 1303/2013. Important elements of the information required are the Feasibility Study and the Cost Benefit Analysis (CBA). Moreover the CBA is necessary to submit request for financing by EIB or other financial institutions.

The aim of this document is to describe the technical specifications for the tendering of the Feasibility Study, Cost Benefit Analysis and the provision of supporting services to IPTO.

### 2. Feasibility Study

[3] http://www.admie.gr/to-systima-metaforas/anaptyxi-systimatos/dekaetes-programma-anaptyxis-systimatos-metaforas-dpa/

[4] Annex III provides the estimated budget of the project "Phase II: DC interconnection, 2×350MW capability, Crete – Attica" and its components

The Feasibility Study focuses on the evaluation of alternative solutions for the future supply of the island of Crete, taking into consideration the environmental constraints set by the EU Directives 75/2010 and 2192/2015 regarding the evolution of the generation mix in the power system of the island.

A feasibility analysis has been performed by IPTO for the preparation and submission of the TYNDP 2017-2026. The Consultant shall review the analysis performed by IPTO and present it in the more rigorous format of a Feasibility Study. IPTO will provide to the Consultant all the available relative information.

## 3. Cost Benefit Analysis (CBA)

The project "Phase II: DC interconnection, 2×350MW capability, Crete – Attica" is considered as "Major Project" in the framework of EU funds (Article 100 of Regulation (EU) No 1303/2013). Its total eligible cost amounts approximately to € 720 million[5] (excluding contingencies and VAT), exceeding the € 75 million financial threshold set by the above regulation and certain other provisions.

The CBA is an analytical tool for judging the economic advantages or disadvantages of an investment decision by assessing its costs and benefits in order to assess the welfare change attributable to it and the contribution to EU cohesion policy objectives. The Cost Benefit Analysis is explicitly required, among other elements, as a basis for decision making on the co-financing of major projects included in operational programmes (OPs) of the European Regional Development Fund (ERDF) and the Cohesion Fund.

The CBA, including a financial and economic analysis and a risk assessment, constitutes a crucial part of the information required for the approval of a major project (Article 101 of Regulation (EU) No 1303/2013).

The CBA will be carried out by taking into consideration and complying with:

a) The **Guide to Cost Benefit Analysis of Investment projects**[6], Economic appraisal tool for Cohesion Policy 2014-2020" (issued by EC, Directorate General for Regional and Urban policy) for "major projects" (hereinafter referred as **"CBA Guide"**).

b) the **"Climate Change and Major Projects"** [7]Outline of the climate change related requirements and guidance for major projects in the 2014-2020 programming period.

[5] Annex III provides the estimated budget of the project "Phase II: DC interconnection, 2×350MW capability, Crete – Attica" and its components

[6] http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

[7] https://ec.europa.eu/clima/sites/clima/files/docs/major_projects_en.pdf

Climate change adaptation and mitigation considerations are integrated in the preparation and approval of major projects.

The CBA is structured in the following seven steps:

### *3.1 Description of the context*

Description of the social, economic, political and institutional context in which the project will be implemented.

### *3.2 Definition of the objectives*

From the analysis of all the contextual elements provided from the previous step the regional and/or sectorial needs that can be addressed by the project must be assessed, in compliance with the sectorial strategy prepared by Greece and accepted by the European Commission.

### *3.3 Identification of the project*

Includes:

- the physical elements and the activities (type of infrastructure, type of intervention, service provided, location, etc.) that will be implemented and to achieve a well-defined set of objectives.
- the body responsible for implementation and its technical, financial and institutional capacities
- the impact area and the final beneficiaries

### *3.4 Technical feasibility & Environmental Sustainability*

Technical feasibility and environmental sustainability are among the elements of information to be provided in the funding request for major projects. Although Technical Feasibility and environmental sustainability are not formally part of the CBA, their results must be concisely reported and used as a main data source within the CBA. Detailed information should be provided on: demand analysis, options analysis, environmental and climate change considerations, technical design, cost estimates and implementation schedule.

### *3.5 Financial Analysis*

The **Financial Analysis** is carried out in order to:

- assess the consolidated project profitability
- assess the project profitability for the project owner (IPTO)
- verify the project financial sustainability.

It is carried out in accordance with the Discounted Cash Flow (DCF) method and in compliance with the Commission Delegated regulation 480/2014.

The main parts of the Financial analysis refer to:

- investment cost, replacement costs and residual value
- operating costs and revenues
- sources of financing (EU grant, national public contribution, loans or equity, etc.)
- financial profitability
- financial sustainability

The inflows for the financial analysis include:

- operating revenues from the provision of services (charges paid by the users, ITC revenues, etc.)
- sources of financing
- subsidies and other financial gains

The outflows relate to the following:

- Development costs (e.g. studies, rights of way, environmental planning) and project management costs
- Material and assembly cost, including installation and commissioning
- Other construction costs, including temporary solutions, waste management and environmental costs
- Operating costs (incl. ITC costs)
- Maintenance costs
- Replacement cost
- Reimbursement of loans and interest payment
- Taxes on capital/income and other direct taxes

The **project profitability** is measured by the following key indicators[8]:

- Financial Net Present Value **FNPV (C)** and Financial Rate of Return **FRR (C)** on investment (before EU grant)
- Financial Net Present Value **FNPV (K)** and Financial Rate of Return **FRR (K)** on national capital (after EU grant).

The calculation of the above key indicators contributes to deciding if the project requires EU financial support. The **funding gap rate** quantifies the needed grant (EU and national contribution/grant).

The **financial sustainability** of the project will also be verified. The project is considered as financially sustainable when the risk of running out of cash in the future, both during the investment and the operational stages is negligible.

[8] see Annex IV

The difference between inflows and outflows will show the deficit or surplus that will be accumulated each year of the analysis. Sustainability occurs if the generated cumulative cash flow is positive for all the years considered.

It is important to ensure that the project does not risk suffering from a shortage of capital. Proof of disposal of sufficient resources to cover future costs should be provided in the sustainability analysis.

### *3.6 Economic Analysis*

An economic analysis should be carried out to appraise the project's contribution to social welfare. The key concept is the use of shadow prices to reflect the social opportunity cost of goods and services, instead of prices observed in the market, which may be distorted.

The standard approach, consistent with international practices, is to move from financial to economic analysis. Adjustments such as fiscal corrections, conversion from market to shadow prices and evaluation of non-market impacts and correction for externalities will be taken into account.

After market prices adjustment and non-market impacts estimation, costs and benefits occurring at different times will be discounted by using the Social Discount Rate.

In the calculation of benefits, applying the "CBA Guide", the consultant could also take into consideration the CBA methodology developed by ENTSO-E (final version approved by the European Commission, 5 Feb 2015) (ENTSO-E CBA methodology)[9].

Once all the costs and benefits of the project have been quantified and valued in money terms the economic performance of the project will be measured by calculating the following indicators (Annex V):

- **Economic Net Present Value (ENPV):** the difference between the discounted total social benefits and costs
- **Economic Rate of Return (ERR):** the rate that produces a zero value for the ENPV.
- **B/C ratio**: the ratio between discounted economic benefits and costs.

### *3.7 Risk Assessment*

The recommended steps for assessing the project risks are:

- ***sensitivity analysis***

[9] www.entsoe.eu/Documents/SDC%20documents/TYNDP/ENTSO-E%20cost%20benefit%20analysis%20approved%20by%20the%20European%20Commission%20on%204%20February%202015.pdf

It enables the identification of the critical variables of the project. Such variables are those whose variations have the greatest impact on a project's financial and economic performance. The sensitivity analysis is carried out by varying one variable at a time and determining the effect of that change on the FNPV and ENPV. As critical variables could be chosen those for which a variation of +/-1% of the value adopted in the base case gives rise to a variation of more than 1% in the value of the FNPV and ENPV.

- ***qualitative risk analysis*** (incl. risk matrix)

Shall include the following elements:

- a list of adverse events to which the project is exposed
- a risk matrix for each adverse event
- an interpretation of the risk matrix including the assessment of acceptable levels of risk
- a description of mitigation and/or prevention measures.

- ***Probabilistic risk analysis*** *(required where the residual risk exposure is still significant)*

- ***Risk prevention and mitigation*** *(incl. Risk Management, which is the identification of strategies to reduce risks and based on risk assessment)*

Analytical description of each step is presented in the CBA Guide.

**3. Provision of supporting services to IPTO for the submission of the Major Project Dossier to the European Commission.**

The Consultant will support IPTO in the submission of the Major Project Dossier to the European Commission with regard to the Feasibility Study and the CBA until their final approval by the Commission (DG Com and DG Regio). In this context the Consultant will answer all possible questions by the Commission related to these studies and will modify them if required, until the final approval by the Commission.

**4. Deliverables**

- ***Feasibility Study***
- ***Cost Benefit Analysis (CBA),*** *fully applying the "CBA Guide" and the "Climate Change and major projects".*
- ***Executive Summary of CBA***
- ***Provision of supporting services to IPTO up to the final approval of the Feasibility Study and the CBA by the Commission***

**5. Time schedule**

The deadline for the completion of the Feasibility Study and the CBA and their submission to IPTO is three months (90 calendar days) from the date of signing of the respective contract. For the second phase of the project which relates to the support to be given to IPTO with respect to the submission of the above studies to the European Commission, as part of the Major Project Dossier, the time schedule is 12 months from the date of signing of the respective contract.

**ANNEX I: PROJECT OF INTERCONNECTION OF CRETE WITH THE MAINLAND SYSTEM (HETS)**

**extract from the national TYNDP 2018-2027 regarding the project of Crete interconnection to the mainland (Phase I and Phase II)**

# 1 Interconnection of Crete with the Mainland System

The System of Crete is characterized by:

- Very high variable cost of production because of the use of oil in the local power stations, which is reflected as a significant charge on the consumers for the coverage of the Public Service Obligation (PSO) (more than €300 millions annually).
- Large annual increase rate of the island's load (~5% until 2008 as much for electricity demand, as for the annual peak, which decreases to 1% and 3.9% respectively during the last three years). It must be noted that the demand during the summer months was barely covered by the local stations.
- The big difficulty, almost impossibility to seek locations and to insure permissions for the enhancement of the local stations or the development of new.
- The continuous increase of interest for the exploitation of the enrich local potential of RES, the penetration of which in the island's generation mix is limited due to technical constraints (basically because of important stability issues which the high penetration of RES might create to an autonomous electrical system as such as that of Crete).
- Low level of reliability of supply, especially in cases of power system failure.

The above mentioned characteristics have led to the examination of the island's interconnection with the Mainland System, fact which would contribute excessively to the total or partial settlement of the majority of issues that the electricity system of Crete faces today.

In the meantime from the release of the Preliminary Draft Version of the present TYNDP (for which Public Consultation was held from February 9 until March 9 2016), an emerging need to adapt in the new situation stemming from the application of the Directives 2010/75/EU and 2015/2193/EU appeared. According to the above Directives, the application of these Directives will increase the possibility of generation adequacy problems for the Power System of Crete in the forthcoming years (taking into account the advanced age of most of the existing units). Considering the above (PSO high cost and possible appearance of generation adequacy issues in the near future), **the interconnection subject of Crete appears to acquire an "urgent" character, rendering *the implementation time as the most critical parameter* for the selection of the technical solution for the interconnection.**

Taking into account the new data which are formed from the application of the Directives 2010/75/EU concerning industrial emissions and 2015/2193/EU for the limitation of emissions of certain pollutants into the air from medium combustion plants, during the former period, different interconnection topologies of the island where examined anew, thoroughly and in depth, and a multi-criteria valuation of pros and cons was made. In this framework, a large number of possible solutions concerning the connection points, the size (transmission capacity) and the type of interconnection network (AC & DC) were examined.
Considering the results of the above exploration, the interconnection of the island was shortlisted into two phases as follows:

- **Phase I:** 150kV AC interconnection, 2×200MVA capability, Crete – Peloponnese

- **Phase II:** DC interconnection, 2×350MW capability, Crete - Attica

The analytical description of each phase is forth in the following paragraphs.

## 1.1 PHASE I: 150kV AC INTERCONNECTION 2x200MVA CRETE-PELOPONNESE

The scenario for the interconnection of Crete with Peloponnese using AC technology can be summarized as follows:

- **Voltage – Transfer capacity**
  Phase I of the interconnection of Crete (AC link between Crete and Peloponnese) can be implemented by using two 150kV AC circuits, with a transfer capacity of 200MVA each (maximum transfer capacity that has been used in such projects in Greece). The transfer capacity of the link is estimated to a range of 150 to 180 MW.

- **Connection point in Peloponnese**
  In the case of installing AC cables, the minimization of the submarine route is necessary for the project cost optimization and the reduction of the reactive compensation requirements which are in any case always considerable. Because of these considerations, as the connection point in Peloponnese, the area of cape Maleas has been initially selected. The construction of a 150kV double circuit transmission line with heavy type conductors (T.L. 2B/150kV) is required for the connection to the Mainland System.
  Aiming at the acceleration of the permit granting process, part of the terrestrial route in Peloponnese shall be implemented with a double circuit overhead line of 2B/150 kV from Molai s/s to the transition terminal station and from the transition terminal station to a sea shore nearby Neapoli with underground cables of 10 km in lenght, with two 1x3 cable circuits of 200MVA transfer capacity each. From the shore nearby Neapoli, two submarine 3 – phase cables of 200MVA each will be installed all the way to a beach in the Gulf of Kissamos and from there via underground cables to Chania I substation. Additionally, it will be necessary to upgrade the existing 150kV light type, single circuit transmission line (T.L. E/ 150kV) Megalopoli-Sparti-Skala-Molai, to a T.L. 2B/150kV. These projects can be implemented in a relatively short time compared to similar projects, and their associated cost is considered to be small.

- **Connection point in Crete**
  The connection point in Crete shall be located in the west part of the island, at the substation Chania I for the minimization of the submarine route. Such a choice contributes to the reduction of the reactive power compensation requirements and the minimization of the submarine cables cost. Taking into account the transfer capacity of the interconnector as well as the high production cost of the generation units in the thermal power station of Chania, it is concluded that in the short term, no additional reinforcements shall be needed for the transmission network of Crete, a fact that contributes in the acceleration of the project implementation.

A detailed analysis of the projects comprising Phase I is as follows:

- Undergrounding of a small section (1,5 km) of the overhead 150 kV T.L. of Rouf – Ladonas due to upgrading of the 150 kV T.L. Megalopoli – Sparti I.

- Upgrade of the existing T.L. E/150kV Megalopoli I - Sparti II - Sparti I – Skala - Molai, total length of 109.6km, to T.L. 2B/150kV. The project also includes the replacement of the conductors from E to B in the existing T.L. Sparti II – System, 2.6km length.
- Construction of a new 150kV transmission line bay in the existing S/S Megalopoli I, for the connection of the second circuit of the upgraded transmission line mention above.
- Upgrade of two 150kV simple transmission line bays to fully equipped ones in the existing S/S Sparti II, in the framework of upgrading the existing transmission line Megalopoli I - Molai.
- Construction of three new 150kV transmission line bays in the existing S/S Molai, for the connection of the second circuit of the upgraded transmission line mentioned above as well as for the connection of the two new circuits of the Crete interconnector.
- Construction of a new 150kV double circuit transmission line from the S/S Molai to the sea shore next to Neapoli (landing point of the submarine cables). This transmission line will include the following parts:

  - An overhead double circuit line, 28.6 km in length, from the Molaoi s/s to the transition terminal station of SE Peloponnese.
  - An underground double circuit, 10 km in length, from the transition terminal station of SE Peloponnese to the sea shore next to Neapoli.

- Construction of a new 150kV transition terminal station in SE Peloponnese. This station will be the connection node for the overhead line towards S/S Molai and the cables towards the S/S Chania I and will be constructed using GIS technology. The new station will include a double 150kV busbar, equipped with a coupler, four 150kV transmission line cable bays for the connection of the lines from and towards the Molai and Chania I substations, and seven new 150kV shunt reactors in the new terminal S/S (3 per connection circuit to Crete and a spare one), for the compensation of the reactive power produced by the cable parts of the 150kV double circuit line SE Peloponnese-Chania I. The nominal capacity of each shut reactor is estimated to be 40MVAr maximum, however the finalization of their capacity will be decided later, according to the parameters of the cable circuits.
- Construction of a new 150kV double circuit submarine line between the landing points in SE Peloponnese (near Neapoli) and west Crete, with a total length of 132 km.
- Construction of a new 150kV double circuit underground line from the landing point in west Crete to the Chania I S/S, with a total length of 34km.
- Construction of two new 150kV transmission line bays in the existing Chania I S/S, for the connection of the two cable circuits from SE Peloponnese, as well as seven new 150kV shut reactors' bays and shunt reactors (3 per cable circuit from SE Peloponnese and a spare one), for the compensation of reactive power produced by the cables of the 150kV line SE Peloponnese-Chania I. The capacity of each inductor is estimated in the order of 40MVAr, but the finalization of their capacity will be decided in a later time, according to the parameters of the cable circuits.

Additionally, the installation of a Static Var Compensator (SVC) in Crete will be required for the necessary voltage regulation. The SVC will be installed nearby Linoperamata S/S and its size shall be ± 60Mvar.

## 1.2 Phase II: Interconnection DC 2×350MW Crete - Attica

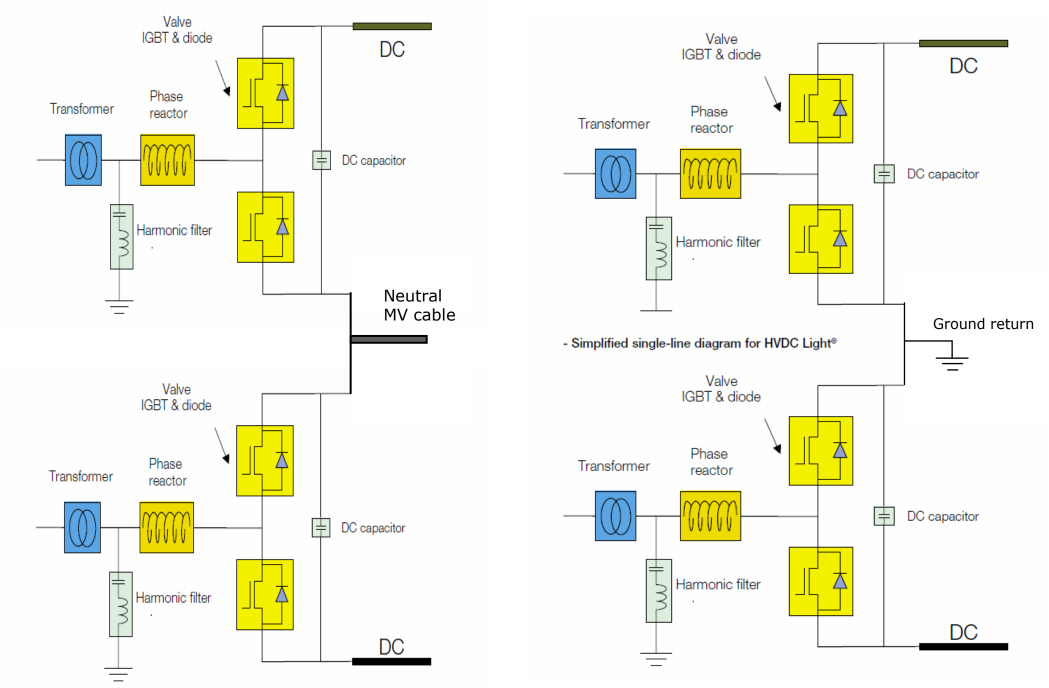
This interconnection in general lines contemplates the followings:

- **Technology**
  The selection of Voltage Source Converter (VSC) links, compared to Line Commutated DC links are the most reasonable solution as they enable

  - the connection of a weak System (as that of Crete) even with a small local production, and also
  - rapid change and reverse of power flow without interruption.
  - Reactive power regulation and black start-up, capability

  The DC interconnection technology with VSC accounts already plenty applications worldwide and is considered to be ripe and reliable, being today available from more than one manufacturers, fact which is important for the tender stage.

  For the HVDC link topology, two technical solutions have been examined, both of them including a bipolar link with two high voltage cables, one for each pole. The transfer capability of each cable will be equal to one half of the total, either by using a medium voltage cable for the neutral connection, or with the utilization of a grounding solution and return through the sea.
  Sea return is widely used in DC technology, especially in long distance applications, as it contributes to the limitation of the project cost, compared to the utilization of a medium voltage cable for the neutral connection. Nevertheless, for the implementation of a sea return solution, the creation of a lagoon (pond) or beach electrode conductor may be necessary for the installation of the grounding electrodes, fact that increases significantly the difficulty in locating the proper areas for the project and to obtain the necessary permissions for the grounding system installation, especially in touristic areas such as Crete, as well as close to harbors or industrial zones like in the case of the landing area in Attica, where the installation of sea return electrodes may cause damages in adjacent metal constructions in the nearby industrial zone. In conclusion, the cost associated to the environmental impacts of such a solution is not negligible and must be taken into account during the final decision.




Type 1: Bipolar DC link with separate poles and use of MV cable as neutral

Type 2: Bipolar DC link with separate poles and use sea bed as ground return

*Figure 1: DC schemes under consideration*

The operation voltage selection of the HVDC links depends on their submarine cable length and their nominal power. High power (e.g. 2x500MW), with the current technical capabilities for VSC Converter stations and submarine cables leads to operating voltages in the order of ≥320 kV.

- **Transfer capability**
  The transfer capability has been determined to 700MW (2x350MW). Nevertheless**, depending on the technical developments in the next years** (operating voltage, unitary cost elements, etc.) and especially **the evolution of large RES projects in Crete, the final size of the interconnector could be re-examined for a possible revision (**up to 1000MW) **according to the emerging needs.**

- **Connection point in Attica**
  The size of the interconnector as well as the achievement of the security of supply of the island along with the need to increase the capability to absorb RES electricity production, are the main reasons to select a strong connection point for the interconnection with HETS. In this respect an appropriate place coterminous to Koumoundouros EHV substation has been identified, for the development of the AC/DC conversion station and in the Koumoundouros EHV substation space has been reserved for the construction of two 400kV bays. A short route with an easy access exists between the converter station and the seaside (considering a landing point in the Elefsis bay, and an underground rout of few kilometers).

- **Connection point in Crete**
  The connection point in Crete must be the center point of the island's load and adjacent to a strong local network, in order to minimize the needs for new transmission projects. The Linoperamata area fulfils these criteria (Korakia location), as the local transmission network is

strong and capable to supply with safety the power provided by the Mainland System, and in the short term, no new projects will be necessary. However, the choice of this point results in an increase of the submarine route and as a consequence, the project's cost.

A detailed analysis of the projects comprising Phase II, is as follows:

- Undergrounding part (~350m in length) of nine (9) circuits of OTL, 150KV in front of the Northwestern side of the existing EHV Koumoundourou substation or elevating in height the nine (9) above mentioned circuits so that the converter station can be installed underneath.
- Construction of a new AC/DC VSC bipolar converter station as well as the connection projects (2 400kV bays,.), at the 400kV side of Koumoundouros EHV S/S.
- Construction of a new 150kV coupling substation in Crete. This substation shall be constructed using GIS technology, and will include a double 150kV busbar with a coupler, and six 150kV transmission line bays of the connection to the 150kV transmission network circuit of Crete and 2 transformer bays for the converter substation connection.
- Construction of a new AC/DC VSC bipolar converter substation in Crete (Damasta).
- Construction of a DC cable link, connecting the conversion stations of Attica with Crete. This cable link shall include:
  - An underground DC circuit (two cables plus an electrode MV DC cable and an F.O. cable), ~32km length, from the converter station (Koumoundouros) to the landing point in Attica region (Pachi Megara) .
  - A submarine DC circuit (two cables, ±) , with F.O. cable, with an approximate length of 328km, from the landing point in Attica to the landing point in Crete (Korakia).
  - An underground DC circuit (two cable, ±) and a F.O. cable of an approximate length of 250m from the landing point in Korakia to the transition terminal station in Korakia.
  - A transition terminal station in the Korakia (Crete) for the transition of the DC submarine cables to overhead DC transmission line.
  - An overhead DC circuit, ~6 km length (two cables ± plus a F.O. cable, plus an electrode conductor for a length of 4km only), from the transition terminal station of Korakia (Crete) to the converter station AC/DC in Crete (Damasta).
- Upgrade and undergrounding of very small parts of two (2) existing 150 kV overhead transmission lines in Crete needed for the connection to the 150kV coupling AC substation in Crete to the existing Linoperamata S/S.
- Installation of sea grounding electrodes or lagoons in the appropriate location.
- Adding two 150 kV transmission cable line bays in the existing Linoperamata substation.
- Sea bottom survey of the DC submarine cable route
- Construction of two (2) electrode pond or beach stations which will include the following
  - An Electrode pond or beach station at the Stachtoroe rocky small island which is located at a distance of 18km from Pachi Megaron.
  - An electrode submarine MV DC cable, of 18km in length which will connect the electrode station to the underground electrode MV cable at the landing point in Pachi Megaron beach and via the underground MV DC electrode cable to the Converter Station, located next to ehv Kounoundourou substation.
  - An electrode pond or beach station located in the wider area of Korakia (Crete) at a distance of about 10,6km from the converter station of Damasta (Crete).
  - An overhead or underground MV DC electrode line of length of 6,7km which will be connected to the overhead DC transmission line at a tower of this line which is at a distance of 4km away

from the Converter station of Damasta (Crete)and thus via the overhead DC transmission line to the Converter station of Damasta (Crete).

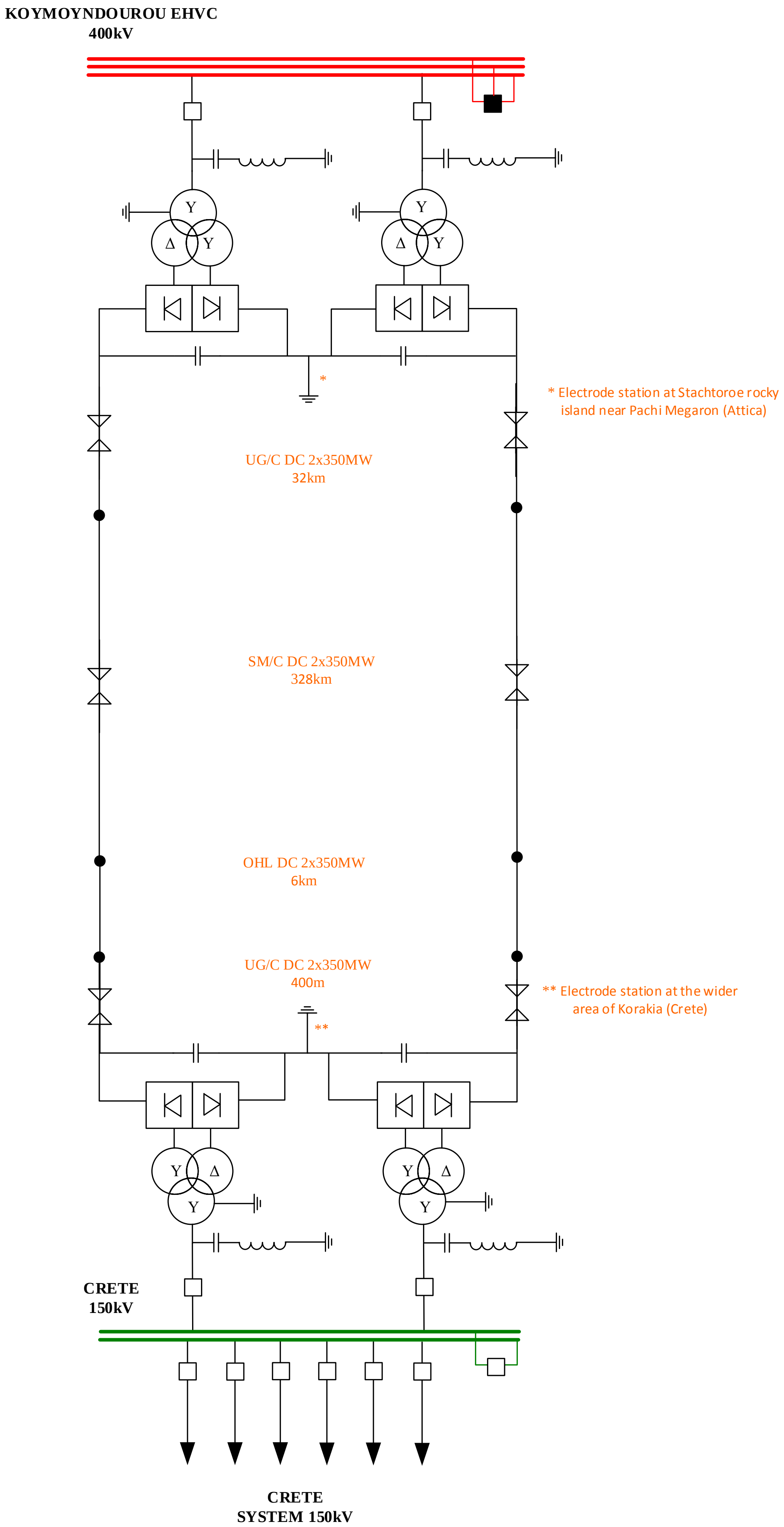
## *1.3 Implementation of the Crete interconnection projects*

**The design and permit granting processes for both phases are implemented simultaneously**. In any case, the immersion of cables shall be implemented after the finalization of the permitting processes and the land acquisition that are necessary for the terrestrial parts of the project.
Finally, IPTO in close cooperation with the Operator for the non-Interconnected Islands (HEDNO) will perform additional technical studies for the determination of the necessary reinforcements in the System of Crete in the following years. These reinforcements shall be determined according to the following parameters:

- Interconnection points
- Nominal capacity of the interconnectors
- Loading of the interconnectors
- Different scenarios for the required operation of the local generation units

Concerning the existing development plan for the transmission network in Crete (according to the TYNDP of islands 2014-2018), it is not expected in general to change, however will be reviewed soon in collaboration with HEDNO.

**ANNEX II: UPDATED CONFIGURATION OF THE PROJECT (April 2017)**


KOYMOYNDOUROU EHVC
400kV
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Y
* Electrode station at Stachtoroe rocky
island near Pachi Megaron (Attica)
UG/C DC 2x350MW
32km
SM/C DC 2x350MW
328km
OHL DC 2x350MW
6km
UG/C DC 2x350MW
400m
** Electrode station at the wider
area of Korakia (Crete)
CRETE
150kV
CRETE
SYSTEM 150kV

## ANNEX III: ESTIMATED PROJECT BUDGET AND ITS COMPONENTS

### Table 1. Estimated Project Budget (indicative)

| **Interconnection Crete with HETS (Phase II)<br>Estimated Budget** | **(€ million)** |
|---|---|
| Estimated Budget (Subprojects) | 715,6 |
| Contingencies (9%) | 64,4 |
| Publicity | 0,3 |
| Project Management (PM) | 3 |
| **Total Investment Cost (incl. contingencies)** | **783,3** |
| **Total Investment Cost (excl. contingencies)** | **718,9** |

## Table 2. Subprojects and estimated investment cost breakdown (indicative)

| A/A | Υποέργα | Subprojects | Scenario 1 | Scenario 2 (subproject 9α overhead) |
|---|---|---|---|---|
| Νέο ‘Εργο | 1. Υπογειοποίηση εννέα (9) Κυκλωμάτων εναερίων Γ.Μ. 150 kV έμπροσθεν της βορειοδυτικής πλευράς του υφιστάμενου ΚΥΤ Κουμουνδούρου και σε μήκος 350 μέτρων περίπου ή υπερύψωση του τμήματος των εναερίων Γ.Μ. 150 kV (εννέα κυκλώματα) που βρίσκονται έμπροσθεν της βορειοδυτικής πλευράς του ΚΥΤ Κουμουνδούρου έτσι ώστε να χωροθετηθεί στον χώρο αυτόν ο Σταθμός Μετατροπής Κουμουνδούρου. | Undergrounding a section of 350m in length, of 150kV overhead transmission lines circuits, located in front of the northwestern side of the ehv Koumoundourou substation or elevating in height the same sections of the above nine (9) 150kV TL circuits so that the Koumoundourou Converter Station be installed underneath. | 2.040.000 € | 2.040.000 € |
| 1 | Επέκταση του υφιστάμενου ΚΥΤ 400/150/30 kV Κουμουνδούρου κατά δύο (2) πύλες 400 kV υπογείων καλωδιακών Γ.Μ. για την σύνδεση του ΚΥΤ με τον Σταθμό Μετατροπής Κουμουνδούρου. Ο εξοπλισμός των δύο αυτών πυλών θα ελέγχεται αποκλειστικά από τον Σταθμό Μετατροπής Κουμουνδούρου. | Expansion of the existing ehv 400/150/30kV Koumoundourou substation by adding two 400kV underground cable bays in order this ehv substation to be connected with the Koumoundourou Converter Station. The equipment of these two bays will be controlled from the Koumoundourou Converter Station. | 5.000.000 € | 5.000.000 € |
| (2α) | Σταθμός Μετατροπής Κουμουνδούρου, πηγής τάσεως, διπολικού σχεδιασμού και συνολικής ισχύος 700 MW (2×350 MW) με αντίστροφη λειτουργία, με συμμετρική διπολική λειτουργία και με εγκατάσταση δίπλα στο υφιστάμενο ΚΥΤ Κουμουνδούρου. | Koumoundourou Converter Station, VSC, bipole, of total power of 700 MW (2x350MW), suitable for reverse operation and with symmetric dipole operation. This converter station will be installed next to the existing ehv Koumoundourou substation. | 100.000.000 € | 100.000.000 € |
| (3α) | Δύο υπόγεια καλώδια Σ.Ρ. (+, -), μονώσεως XLPE, συνολικής ισχύος 700MW και τάσεως ≥ ± 320 kV, από τον Σταθμό Μετατροπής έως την περιοχή (παραλία) της Πάχης, Μεγάρων, μήκους 32 km περίπου. Τα δύο καλώδια θα συνοδεύονται και από καλώδιο οπτικών ινών (24 ίνες). | Two underground , DC cables (+ -), of XLPE insulation, of total power of 700MW and of voltage of ≥ ± 320kV, from the Koumoundourou Converter Station all the way to the Pachi Megaron beach, of 32 km in length. These two cables will be accompanied by F.O. cable (24 Fibres). | 485.000.000 € | 485.000.000 € |
| (3β),(3δ) | Ένα υπόγειο / υποβρύχιο καλώδιο Σ.Ρ., Μέσης Τάσης (ΜΤ) ρεύματος 1100 Α, (350 MW/320 kV) μονώσεως XLPE από τον Σταθμό Μετατροπής Κουμουνδούρου έως την παραλία της Πάχης Μεγάρων και από την παραλία της Πάχης υποβρυχίως στην βραχονησίδα Σταχτορρόη στον Παράλιο ή Λιμνοθαλάσσιο Σταθμό Ηλεκτροδίων με συνολικό μήκος 50 km περίπου (32 km υπόγειο και 18 km περίπου υποβρύχιο). | One underground /submarine DC cable, of Medium Voltage (MV), 1100A, XLPE insulation, from the Koumoundourou Converter Station all the way up to the Pachi Megaron beach and from the Pachi beach via subsea to the small rocky island of Stachtoroe electrode pond or beach station, of total length of about 50km (32 km underground and 18 km subsea). | | |
| (3γ) | Υποβρύχια καλώδια Σ.Ρ. (±), μονώσεως XLPE, συνολικής ισχύος 700MW, τάσεως ≥ ± 320 kV από την περιοχή (παραλία) Πάχης Μεγάρων της Αττικής έως την παραλία της Κορακιάς του Δήμου Μαλεβιζίου, του νομού Ηρακλείου της Κρήτης, μήκους 328 km περίπου. Το κάθε καλώδιο θα εμπεριέχει ενσωματωμένες δώδεκα (12) οπτικές ίνες. | Submarine DC cables (±), XLPE insulation, of 700KW of total power, of voltage of ≥ ± 320kV, from the Pachi Megaron beach all the way up to the Korakia beach belonging to the municipality of Maleviziou of the Prefecture of Herakleon Crete, of total length of about 328km. Each cable will contain 12 optical Fibres. | | |

| | | | | |
|---|---|---|---|---|
| (3ε) | Δύο (2) υπόγεια καλώδια Σ.Ρ. (±), μονώσεως XLPE, τάσεως ≥ ± 320 kV και συνολικής ισχύος 700MW από την παραλία Κορακιάς έως τον Τερματικό Σταθμό Μετάβασης της Κορακιάς μήκους 400 m περίπου. Τα δύο καλώδια θα συνοδεύονται και από καλώδιο οπτικών ινών (24 ίνες). | Two (2) underground DC cables (±), XLPE insulation, of voltage of ≥ ± 320kV and of total power of 700MW from the Korakia beach all the way up to the transition terminal station of Korakia of 400m length. The two cables will be accompanied by F.O. cable (24 fibres). | | |
| (3στ) | Νέο υπόγειο τμήμα της μίας εκ των υπό αναβάθμιση εναέριων Γ.Μ. 150 kV Λινοπεράματα – Χανιά, σε μήκος 1.5 km περίπου πριν τον Υ/Σ Λιναπεραμάτων και έως τον Υ/Σ ΑΗΣ Λινοπεραμάτων, με χρήση δύο υπογείων καλωδίων μονώσεως XLPE, ισχύος 200 MVA έκαστον και με αγωγό αλουμινίου διατομής 800 $mm^2$ έκαστον. | New underground section of the one of the two, under undergrounding, overhead AC 150kV transmission lines of Linoperamata – Chania extending in about 1.5km in length, starting before the existing Linoperamata substation and finishing all the way up to existing Linoperamata substation by using two underground cables of XLPE insulation of total apparent power of 200MVA and with aluminum conductor of 800mm2 in cross section. | | |
| (4α) | Παράλιος ή Λιμνοθαλάσσιος Σταθμός Ηλεκτροδίων (beach or pond electrode station) σε παραλία της βραχονησίδας Σταχτορρόης (18 km περίπου από την Πάχη Μεγάρων). Ο Σταθμός θα είναι αντιστρέψιμου τύπου (reversible type). Το υλικό των ηλεκτροδίων θα είναι γραφίτης ή κράμα σιδήρου, πυριτίου και χρωμίου (High Silicon chromium Iron). Ο Σταθμός Ηλεκτροδίων θα είναι κατάλληλος για 1100A Σ.Ρ., το δε εμβαδόν του σταθμού θα είναι ≤ 7.000 $m^2$. Ο Σταθμός ηλεκτροδίων θα συνδεθεί με τον Σταθμό Μετατροπής Κουμουνδούρου με συνολικό μήκος 50 km περίπου**.** | Beach or Pond electrode station located in a beach of the Stachtoroe rocky island (18km away from Pachi Megaron beach). The station will be of reversible type. The electrode material will be graphite or High Silicon Chromium Iron. The electrode station will be suitable for 1110A DC. The area of the electrode station will be ≤ 7000m2. The electrode station will be connected to Koumoundourou Converter Station with a total length of about 50km. | 1.000.000 € | 1.000.000 € |
| (4β) | Λιμνοθαλάσσιο ή παράλιο Σταθμό Ηλεκτροδίων (pond or beach electrode station) σε κολπίσκο της περιοχής Κορακιάς του Δήμου Μαλεβιζίου, του νομού Ηρακλείου της Κρήτης. Ο Σταθμός θα είναι αντιστρέψιμου τύπου (reversible type). Το υλικό των ηλεκτροδίων θα είναι γραφίτης ή κράμα σιδήρου, πυριτίου και χρωμίου (High Silicon chromium Iron). Το εμβαδόν του λιμνοθαλάσσιου ή του παράλιου σταθμού θα είναι περίπου ≤ 7.000 $m^2$. Ο Σταθμός θα είναι κατάλληλος για 1100A Σ.Ρ. Ο Σταθμός θα συνδεθεί με τον Σταθμό Μετατροπής Δαμάστας (Δήμος Μαλεβιζίου, Νομός Ηρακλείου) μέσω του Τερματικού Σταθμού μετάβασης της Κορακιάς. | Pond or beach electrode station located in a small gulf in the wider area of Korakia which belongs to the municipality of Maleviziou of the Herakleon Prefecture, in Crete. The station will be of the reversible type. The material of the electrode will be graphite or High Silicon Chromium Iron. The area of the electrode station will be to ≤ 7000m2. The station will be suitable for 1110ADC. The station will be connected with the Damasta Converter Station located in the Maleviziou municipality via the transition terminal station of Korakia | 1.000.000 € | 1.000.000 € |
| (10) | Τερματικό Σταθμό Μετάβασης στην Κορακιά για την μετάβαση της υπόγειας καλωδιακής γραμμής Σ.Ρ. σε εναέρια γραμμή Σ.Ρ.. Συγκεκριμένα, Μετάβαση δύο (2) καλωδίων Σ.Ρ. (±), τάσεως ≥ ± 320 kV σε δύο (2) εναέριους αγωγούς Σ.Ρ. ίδιας τάσεως και επίσης μετάβαση των 24 οπτικών ινών σε εναέριο αγωγό OPGW. | Transition terminal station of Korakia for the transition of the underground DC line into an overhead DC transmission line. Specifically, two (2) DC cables (±) of voltage of ≥ ± 320kV will be transited to two (2) overhead conductors of DC of the same voltage and also transited the underground F.O. cable to OPGW. | 2.000.000 € | 2.000.000 € |
| (9) | Τρία εναέρια καλώδια Σ.Ρ. ή υπόγειο καλώδιο, Μέσης Τάσεως (Μ.Τ.) και συνολικού ρεύματος 1100A από τον Λιμνοθαλάσσιο ή παράλιο Σταθμό Ηλεκτροδίων της περιοχής Κορακιάς έως ένα πύργο της εναέριας Γ.Μ. Σ.Ρ. τάσεως ≥ ± 320 kV ο οποίος ευρίσκεται σε απόσταση 6,7 km από τον Λιμνοθαλάσσιο ή παράλιο Σταθμό ηλεκτροδίων της περιοχής Κορακιάς. | Three overhead DC cables of MV or underground cable of medium voltage (MV), of total current 1110A DC, from the pond or beach electrode station of Korakia, located in the wider Korakia area, all the way to a tower of the overhead DC line of voltage ≥ ± 320kV which tower is located 6,7 km away from the pond or beach electrode station of Korakia. | 1.900.000 € | 201.000 € |

| | | | | |
|---|---|---|---|---|
| | Εναέρια Γ.Μ. Σ.Ρ., τάσεως ≥ ± 320 kV, με δύο (2) αγωγούς (±), συνολικής ισχύος 700MW και ρεύματος 1100 A (350 MW/320 kV) από τον Τερματικό Σταθμό Μετάβασης της Κορακιάς έως τον Σταθμό Μετατροπής στην Δαμάστα του νομού Ηρακλείου Κρήτης, μήκους 4,65 km. Η γραμμή θα υλοποιηθεί με πύργους σειράς ¨6¨και αγωγούς ACSR/ Cardinal και OPGW με 24 οπτικές ίνες.Επίσης τμήμα της εν λόγω Γ.Μ. θα εμπεριέχει και εναέριο αγωγό Σ.Ρ. Μέσης Τάσησ (Μ.Τ.) μήκους 4 Km περίπου για την σύνδεση του πύργου που απέχει 6,7 km από τον Λιμνοθαλάσσιο ή παράλιο Σταθμό ηλεκτροδίων της περιοχής Κορακιάς με τον σταθμό μετατροπής Δαμάστας. | Overhead DC transmission line of voltage ≥ ± 320kV with two (2) conductors (±), of total power of 700MW and current of 1110A DC, from the transition terminal station of Korakia all the way up to Damasta Converter Station, of length of 4.65km. The line will be constructed by using towers of the “6” series and ACSR/Cardinal Conductors and OPGW with 24 optical fibres. Also, section of the line will contain an overhead DC, MV conductor of length of about 4km for the connection the tower which is 6.7km for away from the pond or beach electrode station of Korakia with the Damasta Converter Station. | 1.200.000 € | 1.200.000 € |
| (2β) | Σταθμό Μετατροπής Δαμάστας πηγής τάσεως, διπολικού σχεδιασμού, ισχύος 700MW (2×350MW), με αντίστροφη λειτουργία, με συμμετρική διπολική λειτουργία και με εγκατάσταση πλησίον του χωριού Δαμάστα του Δήμου Μαλεβιζίου, του νομού Ηρακλείου Κρήτης**.** | Damasta Converter Station, VSC, bipole, of 700MW in power (2x350MW), of the reversible type, with symmetrical dipole operation, located near the Damasta village which belongs to Maleviriou municipality. | 100.000.000 € | 100.000.000 € |
| (5) | Υποσταθμός Ζεύξης Ε.Ρ. 150 kV Δαμάστας για τη σύνδεση του Σταθμού Μετατροπής με το σύστημα Ε.Ρ. 150 kV της Κρήτης. Ο Υποσταθμός Ζεύξης Ε.Ρ. θα είναι GIS 150 kV και δίπλα στον Σταθμό Μετατροπής Δαμάστας. Θα αποτελείται από δύο (2) ζυγούς 150 kV, έξι (6) πύλες εναέριας γραμμής 150 kV μία (1) πύλη σύνδεσης ζυγών 150 kV και δύο (2) πύλες Μ/Σ πλήρως όμως ελεγχόμενες από τον Σταθμό Μετατροπής Δαμάστας. | AC 150kV coupling substation of Damasta for the connection of the Damasta Converter Station to the 150kV transmission system of Crete. This coupling substation will be GIS and be located next to the Damasta Converter Station. It will be composed of two (2) buses, six (6) overhead transmission line bays, one (1) bus coupler bay and two (2) transformer bays, all controlled from the Damasta Converter Station. | 9.000.000 € | 9.000.000 € |
| (6) | Είσοδο των δύο (2) Γ.Μ. 150 kV Ε.Ρ. μονού κυκλώματος Λινοπεράματα – Χανιά στον Υποσταθμό Ζεύξης Ε.Ρ. 150 kV Δαμάστας και αναβάθμιση των δύο (2) αυτών Γ.Μ. 150 kV Ε.Ρ. μονού κυκλώματος Λινοπεράματα - Χανιά σε δύο (2) Γ.Μ. 150 kV διπλού κυκλώματος (με χρήση αγωγών ACSR/Grosbeak και έξοδο από τον Υποσταθμό Ζεύξης Ε.Ρ. 150 kV) από το σημείο του Σταθμού Ζεύξης Ε.Ρ. 150 kV Ε.Ρ. της Δαμάστας έως τον υφιστάμενο Υ/Σ ΑΗΣ Λινοπεραμάτων (Συνολικό μήκος Γ.Μ. 150 kV εισόδου και αναβαθμιζόμενων 20 km περίπου). | Entering and exiting of two (2) 150KV, AC TL of single circuit, Linoperamata – Chania, into the Damasta AC 150KV Coupling substation and upgrading these two TL from single circuit to double circuit all the way up to the existing Linoperamata substation, with the use of ACSR/Grosbeak conductors. Total length of entering section, exiting section and upgraded sections of the TL of about 20km. | 7.025.000 € | 7.025.000 € |
| (7) | Επέκταση του υφιστάμενου Υ/Σ 150 kV ΑΗΣ Λινοπεραμάτων κατά δύο (2) πύλες καλωδιακών γραμμών μεταφοράς 150 kV**.** | Expansion of the existing Linoperamata substation by two (2) TL 150KV cable bays. | 800.000 € | 800.000 € |
| (8) | Μελέτη Βυθού και Αδειοδοτήσεις | Sea bottom survey and Permits. | 510.000 € | 510.000 € |
| **ΣΥΝΟΛΟ** | | | **716.475.000 €** | **714.776.000 €** |

**ANNEX IV: CALCULATION OF FINANCIAL PERFORMANCE INDICATORS**

**Financial Net Present Value (FNPV)**

This indicator represents the discounted economic cash-flow of the project. It shall be calculated according to the following formula:

$$FNPV = \sum_{t=f}^{c+T} \frac{R_t - C_t}{(1+i)^{(t-n)}}$$

Where:

- ***c*** is the first full year of operation
- ***$R_t$***: is the revenue from the operation in year t (in the revenues of year t+T the residual value of the project is included)
- **Ct** is the sum of CAPEX and OPEX on the year *t*
- ***n*** is the year of analysis
- ***i*** is the Financial Discount Rate (FDR) of the project
- ***f*** is the first year of revenue or cost

If FNPV is positive the project generates a net profit. The FNPV reflects the financial viability of a project in absolute values and it is considered the main financial performance indicator.

**Financial Internal Rate of Return (FIRR)**

This indicator represents the financial viability of the project being its ability to generate revenues higher than its investment and operational costs. The indicator is defined as the discount rate that produces a zero FNPV.

Therefore a project is considered financially desirable if the FIRR exceeds its Financial Discount Rate.

**The Financial Benefit/Cost ratio (FB/C)**

This indicator is the ratio between the discounted benefits and the discounted costs.

$$FB/C = \frac{\sum_{t=f}^{c+T} \frac{R_t}{(1+i)^{t-n}}}{\sum_{t=f}^{c+T} \frac{C_t}{(1+i)^{t-n}}}$$

Where:

- ***c*** is the first full year of operation
- ***$R_t$***: is the revenue from the operation in year t (in the revenues of year t+T the residual value of the project is included)
- **Ct** is the sum of CAPEX and OPEX on the year *t*

- ***n*** is the year of analysis
- ***i*** is the Financial Discount Rate (FDR) of the project
- ***f*** is the first year of revenue or cost

If FB/C exceeds 1, the project is considered as financially efficient as the revenues outweigh the costs on the time horizon.
These performance indicators should be seen as complementary to FNPV.

**ANNEX V: CALCULATION OF ECONOMIC PERFORMANCE INDICATORS**

## Economic Net Present Value (ENPV)

This indicator represents the discounted economic cash-flow of the project. It shall be calculated according to the following formula:

$$ENPV = \sum_{t=f}^{c+T} \frac{R_t - C_t}{(1+i)^{(t-n)}}$$

Where:

- ***c*** is the first full year of operation
- **Rt** is the social benefit induced by the project on year *t*. The benefit on year c+T also includes the Residual Value of the project.) The benefit refers mainly to Socio-Economic Welfare, SEW, which is the benefit indicator B2. Moreover, other monetized benefits, such as benefits from variation of losses (benefit indicator B4), should be taken into account.
- **Ct** is the sum of CAPEX and OPEX on the year *t*
- ***n*** is the year of analysis
- ***i*** is the Economic Discount Rate of the project
- ***f*** is the first year of induced social welfare ( $\Delta SWEU$ ) or cost

If ENPV is positive the project generates a net benefit. The ENPV reflects the performance of a project in absolute values and it is considered the main performance indicator.

## Economic Internal Rate of Return (EIRR)

This indicator represents the economic viability of the project being its ability to generate social welfare higher than its investment and operational costs. The indicator is defined as the discount rate that produces a zero ENPV.

Therefore a project is considered economically desirable if the EIRR exceeds its Social Discount Rate.

## The Economic Benefit/Cost ratio (EB/C)

This indicator is the ratio between the discounted benefits and the discounted costs.

$$EB/C = \frac{\sum_{t=f}^{c+T} \frac{R_t}{(1+i)^{t-n}}}{\sum_{t=f}^{c+T} \frac{C_t}{(1+i)^{t-n}}}$$

Where:

- ***c*** is the first full year of operation
- **Rt** is the social benefit  induced by the project on year *t*. The benefit on year c+T also includes the Residual Value of the project.) The benefit refers mainly to Socio-Economic Welfare, SEW, which is the benefit indicator B2. Moreover, other monetized benefits, such as benefits from variation of losses (benefit indicator B4), should be taken into account.

- **Ct** is the sum of CAPEX and OPEX on the year *t*
- ***n*** is the year of analysis
- ***i*** is the Economic Discount Rate of the project
- ***f*** is the first year of induced benefit or cost

If EB/C exceeds 1, the project is considered as economically efficient as the benefits outweigh the costs on the time horizon.
These performance indicators should be seen as complementary to ENPV and as a way to assess/compare projects of different sizes (different level of costs and benefits).