Overview of the Greek power system
Challenges and development plan for
the transmission system

Presentation for First SEERC Conference

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IPTO – GREEK NC CIGRE
Basic Info for the Greek power system

- Area: 131 957 km²
- Population: 10 815 197 (2012)
- Number of electricity consumers: 7 392 722 (2013)
- TSO: IPTO
- DSO: HEDNO
- Peak load: 10 610 MW (2007)
- Average interruption of electricity: 21.4 min
The economic recession resulted in a considerable **reduction of electricity consumption**:
- \( \sim 10\% \) reduction in annual energy consumption compared to the maximum annual energy consumption (recorded in 2008)

This load reduction reflects similar reduction in IPTO forecasts for consumption in next decade compared to older forecasts:
- According to the forecasts of IPTO, consumption will reach 2008 levels (historical maximum) after the end of the current decade

The increase in **distributed generation** (mainly solar) resulted in a reduction of peak power demand and power transfer needs (~9% contribution in 2015)
EVOLUTION OF THE TOTAL NET ELECTRICITY DEMAND

Remark: Pumping is not included
IMPACT OF DISPERSED RES GENERATION ON ELECTRICITY DEMAND

Impact of dispersed RES generation on Demand

(TWh)


- Total demand
- System demand
Impact of dispersed RES generation on Annual Peak Loads

![Impact of dispersed RES generation on Annual Peak Loads](image)

- **Total peak**
- **System peak**
FORECAST OF ANNUAL PEAK LOADS
(*summer noon, without taking into account the dispersed generation*)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Low</th>
<th>Reference (MW)</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>9875</td>
<td>9930</td>
<td>9985</td>
</tr>
<tr>
<td>2018</td>
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<tr>
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<td>11070</td>
</tr>
<tr>
<td>2024</td>
<td>10355</td>
<td>10770</td>
<td>11200</td>
</tr>
<tr>
<td>2025</td>
<td>11040</td>
<td>11500</td>
<td>11980</td>
</tr>
<tr>
<td>2026</td>
<td>11090</td>
<td>11600</td>
<td>12120</td>
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## FORECAST OF EVENING WINTER PEAK LOADS

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Low</th>
<th>Reference</th>
<th>High</th>
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</thead>
<tbody>
<tr>
<td>Year</td>
<td></td>
<td>(MW)</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>9480</td>
<td>9530</td>
<td>9590</td>
</tr>
<tr>
<td>2018</td>
<td>9630</td>
<td>9725</td>
<td>9820</td>
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<tr>
<td>2019</td>
<td>9700</td>
<td>9870</td>
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<td>2020</td>
<td>9760</td>
<td>10000</td>
<td>10230</td>
</tr>
<tr>
<td>2021</td>
<td>9820</td>
<td>10090</td>
<td>10370</td>
</tr>
<tr>
<td>2022</td>
<td>9860</td>
<td>10180</td>
<td>10500</td>
</tr>
<tr>
<td>2023</td>
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<td>2025</td>
<td>10600</td>
<td>11040</td>
<td>11500</td>
</tr>
<tr>
<td>2026</td>
<td>10650</td>
<td>11140</td>
<td>11640</td>
</tr>
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</table>
Hellenic DSO Data

2014 Data

- **Number of RES installations connected to the interconnected network**: 56,066
- **Total Network length**: 235,100 km
  - High Voltage: 111,042 km
  - Low Voltage: 124,058 km
- **Total installed RES capacity (MW)**: 3,679*
- **Number of customers**: 7.4 million
- **Number of Medium Voltage substations**: 225
- **Number of Medium Voltage Transformers**: 161,900
- **Electricity consumption**: 42,300 GWh

*Corresponds to approximately 75% of the total installed RES capacity in Greece.
MAIN DRIVERS FOR THE HELLENIC TRANSMISSION SYSTEM DEVELOPMENT

- Besides the needs for demand supply, the main drivers for the development of the Hellenic Electricity Transmission System are:
  - Interconnection of Greek islands (security of supply, reduction of the energy cost, environmental issues)
  - Connection of conventional (thermal) generation
  - Connection of RES generation

- Major problem: Reaction of the public and delays in the permitting process.

- The progress towards the National and European targets for an increased RES penetration (40% in the electricity sector) is already noticeable
## EXISTING THERMAL POWER STATIONS
(till 31.12.2015)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Installed capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignite</td>
<td>4462</td>
</tr>
<tr>
<td>Oil</td>
<td>730</td>
</tr>
<tr>
<td>Natural Gas (combined cycle)</td>
<td>3999,8</td>
</tr>
<tr>
<td>Natural Gas (open cycle)</td>
<td>308,5</td>
</tr>
<tr>
<td>Dispatched CHP plants</td>
<td>334</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>9834,3</strong></td>
</tr>
<tr>
<td>Technology</td>
<td>Installed capacity (MW)</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Lignite</td>
<td>660</td>
</tr>
<tr>
<td>Natural Gas (combined cycle)</td>
<td>811</td>
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<tr>
<td>Hydro (storage)</td>
<td>242</td>
</tr>
<tr>
<td>Hydro (pump storage)</td>
<td>590</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2303</strong></td>
</tr>
</tbody>
</table>
## SCHEDULED INSTALLED CAPACITY OF RES POWER STATIONS AND CURRENT SITUATION

<table>
<thead>
<tr>
<th>Technology</th>
<th>Target 2014 (MW)</th>
<th>Target 2020 (MW)</th>
<th>Installed RES capacity till 31.12.15 (MW)</th>
<th>RES capacity with Binding Connection Offers (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydros (Conventional &amp; Small)</td>
<td>3700</td>
<td>4650</td>
<td>3018+224=3242</td>
<td>832+26=858</td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>1500</td>
<td>2200</td>
<td>2444</td>
<td>30</td>
</tr>
<tr>
<td>Solar thermal</td>
<td>120</td>
<td>250</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wind farms</td>
<td>4000</td>
<td>7500</td>
<td>1775</td>
<td>2020</td>
</tr>
<tr>
<td>Biomass / Biogas</td>
<td>200</td>
<td>350</td>
<td>52</td>
<td>35</td>
</tr>
</tbody>
</table>

Additional 100 MW of High Efficiency CHP in operation
ELECTRICAL ENERGY PRODUCTION FROM RES & HIGH EFFICIENCY CHP POWER PLANTS

RES GENERATION

ENERGY (MWh)

YEAR

CAPACITY (MW)

WF  Sm.Hydro  B.M/G  heCHP  PV  PV Roof  CAPACITY
INSTALLED CAPACITY OF RES AND LARGE HYDROS

INSTALLED CAPACITY OF RES AND LARGE HYDRO

YEAR

CAPACITY (MW)

WF  Sm.Hydro  BIOM./G  heCHP  PV  PV Rooftop  large HYDRO
CONTRIBUTION OF DIFFERENT FUELS AND IMPORT-EXPORT BALANCE
CONTRIBUTION OF DIFFERENT FUELS AND IMPORT-EXPORT BALANCE

Greece: Electricity production - demand (GWh)
CONTRIBUTION OF RES TO THE TOTAL DEMAND SUPPLY

![Graph showing the contribution of RES to the total demand supply from 2008 to 2016. The blue line represents TOT RES, and the red line represents RES %. The graph indicates a steady increase in RES % over the years, with fluctuations in TOT RES.](image-url)
THE MOST IMPORTANT TRANSMISSION PROJECTS FOR THE PERIOD 2017-2026

- Interconnection of Cyclades to the Mainland System
  - Phase A under construction (estimated commissioning: 2017)
  - Phase B: 2018
  - Phase C: 2022

- New 400 kV overhead line Lagadas – Filippi
  - Under construction (estimated commissioning: 2017)

- Development of the 400 kV in the Peloponnese peninsula
  - Corridor Megalopoli-Korinthos-Koumoundouros: 2021

- Interconnection of Crete to the Mainland System
  - Phase I (AC 2x200 MVA from Peloponnese): 2020
  - Phase II (DC 2x350 MW from Attica): 2024 (50% capacity till 2022)

- 2nd BG-GR tie-line N.Santa (GR)-Maritsa (BG) (PCI, 2021)

- New EHV S/S Rouf (2024)
INTERCONNECTION OF CYCLADES TO THE MAINLAND SYSTEM (Phase A - 2017)
INTERCONNECTION OF CYCLADES TO THE MAINLAND SYSTEM
(Phase B - 2018)
INTERCONNECTION OF CYCLADES TO THE MAINLAND SYSTEM
(Phase C - 2022)
INTERCONNECTION OF CRETE TO THE MAINLAND TRANSMISSION SYSTEM (*crucial parameters*)

- Annual energy consumption $\sim 3$ TWh ($\sim 6\%$ of the total National consumption)
- An annual surcharge of over $300$ M€ distributed to all consumers
  - Local oil power plants of high operation cost, consisting of old power units, with low efficiency, low availability and significant environmental impact
- Great difficulties in land purchase for the enhancement of the existing local generation or the development of new plants
- Continuous increasing interest for the exploitation of the significant RES potential in Crete
  - RES penetration is limited due to significant stability issues likely appear in an isolated power system like that of Crete
INTERCONNECTION OF CRETE TO THE MAINLAND TRANSMISSION SYSTEM
(Current challenges)

- Necessary adaptation to new conditions:
  - Directive 2010/75/EC on industrial emissions
  - Directive 2015/2193/EC on the limitation of emissions of certain pollutants into the air from medium combustion plants

- In the coming years Crete power system will probably face significant and increasing power adequacy issues (taking into account the age of the majority of the existing power units)

- The interconnection of Crete becomes «urgent», indicating the implementation time schedule as the most critical parameter for the selection of the appropriate technical solution for the interconnection
BENEFITS FROM THE INTERCONNECTION OF CRETE TO THE MAINLAND TRANSMISSION SYSTEM

- Increase of the security of supply on the island
- Significant savings of fuel costs, with direct effect to the “Public Service” Obligation, which surcharges all national consumers
- Significant savings of high investment costs for the development and conversion of local power plants
- Better exploitation of the high RES potential (notably the very high wind potential), which is currently very limited due to stability issues in small size autonomous systems
- Drastic reduction of the environmental impact caused by the continuous operation of the local power stations, many of which are located in residential areas
- Contribution to the reduction (and in long term the elimination) of CO₂ pollutants and associated costs
- Allows the expansion of the "Energy Market" to the interconnected islands
LAYOUT OF CRETE INTERCONNECTION TO THE MAINLAND POWER SYSTEM
PHASE I: AC 150kV 2×200MVA INTERCONNECTION CRETE - PELOPONNESE

- Commissioning date
  - The estimated commissioning date (without significant legal or other complications) is by the beginning of 2020 → achieve the target of the most possible fast implementation

- Technical assessment: Analysis of steady-state (N and N-1) and dynamic operation in abnormal conditions, for various load and RES scenarios
  - The completion of Phase I provides a transmission capacity of 200 ÷ 270 MW from HETS to the System of Crete
  - Security of supply level in Crete power system will be significantly high compared to the current conditions: The response to abnormal conditions related to loss of generation is achieved without any need for load shedding
  - Drastic reduction of the necessary spinning reserve (of extremely high cost)
  - Transmission losses Molai – Chania: ~90÷160 GWh/year
PHASE I: AC 150kV 2×200MVA INTERCONNECTION CRETE - PELOPONNESE

- Contribution to saving of “Public Service” Obligation
  - The contribution of the interconnection to the supply of loads in Crete is estimated to ~1200÷1850 GWh/year (40%÷60% of the total demand in the island) → Significant reduction of the operation cost

- Significant savings of high investment costs for the development of new power plants

- Enhancement and expansion of 150 kV transmission system in Lakonia
  - The necessary projects for the decongestion in the area and for the improvement of the security of supply (new 150 kV S/S in Neapoli and a new 150 kV transmission line for its connection to the System), can be combined with the projects of Phase I of the interconnection of Crete, leading to the simultaneous achievement of multiple targets
PHASE I: AC 150kV 2×200MVA INTERCONNECTION CRETE - PELOPONNENSE

- Decongestion of Peloponnese until the completion of 400kV projects
  - Contribution of the absorption of the power generated by the new NG combined cycle unit «Megalopoli V»

- Power flow
  - First years of operation: Flow direction Peloponnese → Crete
  - High RES development: Significant restrictions in export capacity in the direction Crete → Peloponnese (not eliminated after the completion of 400 kV projects in Peloponnese) → need for Phase II

- Conclusion
  - Cost: ~ 330 M€, with extremely short depreciation time
  - The current issues in Crete (limited reliability and high production cost) are overcome in a great extend
  - Safe cost estimation, avoiding significant technical/environmental issues compared to a DC solution
PHASE II: DC 2×350MVA INTERCONNECTION CRETE - ATTIKI

- Commissioning date
  - Extended requirements for investigations towards the determination of the optimum path due to objective difficulties related to the geological conditions along the cable laying route path
  - Environmental issues
  - Probable needs for the development of special technologies (Research & Development)
  - The estimated commissioning date (without significant legal or other complications) is by the end of 2024

- Cost
  - High, with wide range of possible values
  - Current estimation: ~700÷1000 M€
**PHASE II: DC 2×350MVA INTERCONNECTION CRETE - ATTIKI**

Implementation in two steps:

- Laying of two cables and operation with half capacity of the DC link (350 MW) till 2022
  - Temporary overcome of the land purchase and granting permissions for the installation of grounding electrode in a lake (lagoon)

- Operation in the full capacity of the link (700 MW) till 2024
  - Completion of the construction of the lagoon and the installation of the grounding electrode
    - or
  - Additional laying of a medium-voltage cable
HEDNO projects for Intelligent Systems

- HEDNO’s strategic projects for the Network modernization and the transition to the new era of "Intelligent Systems":

- HEDNO is currently under technical evaluation of the offers for a telemetering system testing 160,000 smart meters in a pilot project. The meters will be installed in commercial and residential areas, both inland and on islands in order to test the meters in different situations.

- In addition to this pilot, HEDNO will also spend 5 million euros to set up 27 microgrids on islands and 7.6 million euros to set up energy and local control centers for CRETE and RHODES. To that end 3,000 remote control devices and 19,000 smart meters are currently being tendered.
Other HEDNO Projects for modernization of Distribution

- HEDNO’s current Business Plan includes investments amounting to 1.25 bln euro within a 5-year period and 12 Strategic Projects that will constitute the primary "vehicle" to drive materialization of the strategic goals. Among these projects are the following:
  - Five new state-of-the art Distribution Control Centers
  - Roll out of Smart metering at a National level.
  - Island Energy Control Centers providing new management tools and applications
Thank you for your attention