World’s Largest Air-cooled Turbogenerator in operation

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World's largest air-cooled turbogenerator in operation

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- 400 MVA air-cooled generator now in operation in Bahrain
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Main cooling technologies

- Air
- Hydrogen
- Hydrogen + water in the stator winding bars

Cooling system selection criteria are

- Power output
  - Hydrogen is a much more efficient coolant than air
- Overall cost and efficiency balance
  - Air cooled generators are simpler, but limited in power output
  - H2 cooled generators are smaller and more efficient in theory, but more complex, and require specific auxiliary systems
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Development of cooling technologies
Air-cooled technologies : Recent key facts

- **1980-1990**  Constant air cooled generator technology evolution from 100 to 200 MW

- **1990-1995** : Development and market introduction of 250 MW class air-cooled generator. Today, an established standard

- **1995-2000** : Development and tests of 300-400 MW class air-cooled generator, to anticipate the large GT's and combined cycle development
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250 MW class air-cooled generator
TOPAIR 23 type
More than 80 references
GT and ST applications
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300-400 MW class air-cooled generator
TOPAIR 25 type
Type tested at 500 MVA (Class F operation)
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AL-HIDD II Combined Cycle Power Plant - BAHRAIN

KA13E2-3 CC type:

- 3 x 150 MW GT13E2 gas turbines
- 3 x TOPAIR 21 type air-cooled generators
- 1 x 300 MW Steam Turbine
- 1 x TOPAIR 25 type air-cooled generator

Order- NTP
Sept 2001

First ignition - 1st GT
June 2002

Full operation - PAC
July 2004
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AL-HIDD II  Generator for the steam turbine

**TOPAIR 25 type:**
- Rated output : 400 MVA
- Power factor : 0,85
- Active power : 340 MW
- Voltage : 21 kV
- Cooling : AIR
- Excitation : Static
- Operation : IEC Class B

Standardised air-cooled generators with proven technologies on all units, instead of 3 air-cooled + One H2 cooled:
Simplified Plant design, optimised operation and maintenance
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**TOPAIR 25 Generator : Main data**

<table>
<thead>
<tr>
<th>TYPE TEST</th>
<th>&quot;AL HIDD II&quot; DATA</th>
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<tbody>
<tr>
<td>Rated output : 500 MVA</td>
<td>Rated output : 400 MVA</td>
</tr>
<tr>
<td>Power factor : 0.85</td>
<td>Power factor : 0.85</td>
</tr>
<tr>
<td>Active power : 425 MW</td>
<td>Active power : 340 MW (270)</td>
</tr>
<tr>
<td>Rated temperature : 40°C</td>
<td>Rated temperature : 40°C</td>
</tr>
<tr>
<td>Voltage : 23 kV</td>
<td>Voltage : 21 kV</td>
</tr>
<tr>
<td>Cooling : AIR (TEWAC)</td>
<td>Cooling : AIR (TEWAC)</td>
</tr>
<tr>
<td>Operation : IEC Class F 155°C</td>
<td>Operation : IEC Class B 130°C</td>
</tr>
<tr>
<td>Mean &amp; hot spots</td>
<td>Mean &amp; hot spots</td>
</tr>
<tr>
<td>Efficiency : 98.78 %</td>
<td>Efficiency : 98.70 %</td>
</tr>
<tr>
<td>Short Circuit Ratio : 0.432</td>
<td>Short Circuit Ratio : 0.456</td>
</tr>
<tr>
<td>Noise level at 1m : 89.5 dBA</td>
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</tbody>
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Large operational margin
Strong peaking capability
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"TOPAIR 25" generator type test
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"ALL HIDD II" First results in operation

- First rotation Jan 2004
- First coupling Feb 2004
- PAC July 2004
- Several thousand hours in operation up to 270 MW
- Vibration level within standard values (Minor adjustment on air mixer at coolers outlet)
- Stator temperature record: Max 61°C for 27°C cold air (for specific site conditions) 6k colder than calculations
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TOPAIR 25 Generator : Main design features

- Basic design based on experience and proven technologies
- Stator insulation: Single bar VPI (Micadur / Class F +155°C)
- Stator cooling: Indirect / Multichamber cooling
- Rotor cooling: Direct / Axial with subslots
- Larger output achieved by sizes increase: (D+7% L+17%)
- Linear current density (up to +20%) thanks to the following features
- Reverse cooling (6 air coolers just after fans: 17K benefits)
- External air by-pass and air mixer at cooler outlet
- Rotor air inlet guide vanes
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Rotor
Ø 1230 mm
Weight 78 T

Excitation brush gear

Stator core

Stator winding (double roebel)

Terminals

Coolers

Coupling

Casing

Ventilation fan

Bearing

Total weight : 429 T
Total length : 14.1 m
Width : Compatible with railway transportation
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MULTI-CHAMBER / REVERSE COOLING

ROTOR AXIAL COOLING WITH SUBSLOTS

ROTOR AIR INLET GUIDE VANE

ROTOR SLOT SECTION
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Comparison of air-cooled technology with hydrogen

**FIRST COSTS**
- Simpler generator design
- No auxiliary units and less piping
- Less space and simpler foundation
- Less interfaces to other systems
- Simpler layout, lower engineering
- Reduction of delivery time (3 months)
- Faster erection and commissioning

**OPERATION & MAINTENANCE**
- No H₂ and CO₂ supply system
- Less spares parts
- Less maintenance and supervision
- Better availability (less systems)
- Safer and simpler operation
- Only limited efficiency penalty

Typical savings on EPC:
About 40% of initial costs
(1.5 to 2 M$ for 250 MW)

Typical savings for the operator
200 to 400 k$ per year
(Up to 4 M$ in 10 years for 250 MW)
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Typical “Gas” et “Shaft seal oil” systems avoided with Air-cooled technology
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EFFICIENCY

FULL LOAD  pf 0.85
- 250 MW: 98.81 % Air-cooled
- 300 MW: 98.70 % Air-cooled
- 400 MW: 98.78 % Air-cooled
- 400 MW: 98.90 % H2-cooled

kW

Friction and Windage
Iron
Rotor current dependent
Stator current dependent
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WEIGHTS & SIZES

250 MW:
- Air-cooled: 324 T, 11.9 m

300-400 MW:
- Air-cooled: 429 T, 14.1 m

300 MW:
- H2-cooled: 371 T, 13.7 m

400 MW:
- H2-cooled: 425 T, 14.6 m
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Conclusion - Future

- **250 MW class (300 MVA)**: Air-cooled generators are today common and established products.
- **300 MW class (400 MVA)**: Air-cooled generators are in commercial operation.
- **400 MW class (500 MVA)**: Air-cooled technologies are available, validated and tested.

Know-how and experience develops. Preparation of optimized products with focus on reduced sizes and costs, and higher efficiency is on-going to offer soon to plant engineers and operators even more simple and cost effective generator solutions.