GE Oil&Gas

Products and Services for Geothermal Power

03/11/2016
We are GE

2015 Revenues

- **POWER** $21.5B 66K Employees
- **ENERGY CONNECTIONS** $7.6B 47K Employees
- **RENEWABLE ENERGY** $6.3B 13K Employees
- **OIL & GAS** $16.5B 37K Employees
- **AVIATION** $24.7B 45K Employees
- **TRANSPORTATION** $5.9B 13K Employees
- **HEALTHCARE** $17.6B 55K Employees
- **APPLIANCES & LIGHTING** $8.8B 25K Employees

**CAPITAL VERTICALS** $10.8B*

**GE DIGITAL** ~$6B**

*Segment revenues
** Revenue by year end 2016
GE in Africa
No. 1 Company in Infrastructure in Africa - Business in Africa (2008)
Africa footprint growing...

Key facts

2,200+ employees in Africa

Active in 35 countries:
- Infrastructure: Energy, Oil & Gas, Transportation (Rail, Mining), Aviation, Water
- Healthcare
- Capital (GECAS, EFS)

15 Offices, 4 GE facilities

GE Offices
GE Facilities
GE Developing Health Globally™
Flag Planting Countries
GE Geothermal Solutions
GE Geothermal Products & Services Portfolio

- Steam Turbines, Expanders, Electric generators
- Pumps, Compressors, Air Cooled Condensers
- Balance of Plant, full EPC Services and turkey solutions
- Trainings & Maintenance Services
- Diagnostics & Operation support
- Financing Solutions
GE Geothermal Solutions

Best thermodynamic cycle is proposed depending on resources conditions

Binary cycle power plants employ Organic Rankine Cycle:
- Operate at lower water temperatures of about 75-175 °C
- Use the heat from the hot water to boil a working fluid (an organic compound with a low boiling point)

Direct dry Steam power plants
- Use in conjunction with high enthalpy vapour-dominated resources
- Reach the highest efficiency among all geothermal power plants
- Simple to operate
- Require relatively low capital costs

Single and dual flash power plants
- The most common type of geothermal power plants
- Use liquid-dominated hydrothermal resources with medium to high enthalpy
Steam turbines
## GE Steam Turbines

GE steam turbines are available for both condensing and back pressure applications for dry and flash steam plants.

### SG/SDFG Series - Technical specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power output</td>
<td>5-50 MW, 50/60 Hz</td>
</tr>
<tr>
<td>Inlet pressure</td>
<td>up to 30 bar</td>
</tr>
<tr>
<td>Inlet temperature</td>
<td>up to 300°C</td>
</tr>
<tr>
<td>Speed</td>
<td>3,000 / 3,600 rpm</td>
</tr>
<tr>
<td></td>
<td>Reaction w/ optional impulse control stage</td>
</tr>
</tbody>
</table>

**Key Features**

- **Flexibility**: Designed for a wide range of applications, include API and industrial
- **Scalability**: Multiple size, backpressure / condensing type
- **Tailored**: Modular single / double flow concept

### GST Series - Technical specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power output</td>
<td>20-30 MW / 40-55 MW 60/50 Hz</td>
</tr>
<tr>
<td>Inlet pressure</td>
<td>Up to 10 bar (130psig)</td>
</tr>
<tr>
<td>Inlet temperature</td>
<td>Up to 300°C (570°F)</td>
</tr>
<tr>
<td>Speed</td>
<td>3000 / 3600 rpm</td>
</tr>
<tr>
<td>Blading type:</td>
<td>Reaction</td>
</tr>
</tbody>
</table>

**Key Features**

- **Efficiency**: Maximized efficiency thanks to high performance steam path
- **Cost effective**: Low maintenance thanks to advanced moisture removal system
- **Simplicity**: Compact concept
GE References at Lardarello Italy

1904 Piero Ginori Conti generated as the first electricity by geothermal fluid

1913 First geothermal power plant generating 250 KW

1930 Total installed geothermal power 12 MW

- Electric power $7 \times 10^{20-40}$ MW
- SGC4-26 model
- Inlet flange Pressure 2-14 bar
- Inlet flange Temp 100-200 deg C
- 80-130-250 ton/h
- 5% CO2 H2S
- 5 GWh per year

Bearing Span: 4900 mm
Organic Rankine Cycle
The Organic Rankine Cycle

The ORC is a thermodynamic Rankine cycle using an organic working fluid

Advantages over steam:

- Operates at medium temperature geothermal fluid
- Easy operability also in remote controlled and unmanned plants
- Closed loop with zero emissions in the atmosphere

- Low enthalpy liquid resources
- Higher mass flow rate
- Heat recovered at lower temperature
- Lower volumetric flows
- Condensing pressure higher than atmospheric
- Single or two-stage turbines
GE ORC References

Berlin, El Salvador

Geothermal Station supplied as TK Contract
Installed Power: ~58 MW
Steam Turbine SGDFC4-22 rated 45 MW
ORC rated ~13 MW

SGDFC4-22
• Power 45 MW
• Rot. speed 3600 rpm
• Inlet pressure 6-10 bar
• 22 inches LPB
• Radial double exhaust
Castelnuovo ORC Power Plant
GE’s Success Story: Geothermal ORC in Italy

GE as main contractor for ORC power island

Zero emissions total reinjection plant

Resource and Environmental sustainability

GE scope of work

- Detailed engineering.
- Expander generator and complete ORC island.
- Reinjection system, including pumps and compressors.
- Installation, commissioning and start-up.
- Availability and reliability guarantees.

Partnership with Customer

- 2+ Years direct support to Customer for design and permitting.
- Training to support Customer operations
- Financing support.

Main layout and rendering of the power plant and ACC units
Project Overview

- **Total reinjection** of fluids and non-condensable gases
- **Use of medium-high enthalpy** geothermal steam (ORC plants usually use liquid resources)
- **Condensation in the main heat exchanger** in presence of Non-Condensable Gases (NCG)
- **ORC working fluid is cooled by air** with no water consumption
- **Reinjection well on the same drilling pad**, minimizing pipelines
- **Landscape integration** of the ORC plant (1560 m2 curved green roof closed structure)

5 MW of electric net power target

**Turboexpander manufactured by GE Oil&Gas**

**Compression system for NCG manufactured by GE Oil&Gas**
**ORC Plant Characteristics**

**Plant data**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Working Fluid</td>
<td>R245fa</td>
</tr>
<tr>
<td>WF mass flow</td>
<td>kg/s</td>
</tr>
<tr>
<td>TEX T inlet</td>
<td>°C</td>
</tr>
<tr>
<td>Geofluid Delta T</td>
<td>180°C – 89°C</td>
</tr>
<tr>
<td>ACC</td>
<td>seven bays, with VFD</td>
</tr>
<tr>
<td>Evaporator</td>
<td>off-line cleaning</td>
</tr>
</tbody>
</table>

**Design case Power**

<table>
<thead>
<tr>
<th></th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected gross power</td>
<td>6525</td>
</tr>
<tr>
<td>ORC pump consumption</td>
<td>570</td>
</tr>
<tr>
<td>NCG compressor consumption</td>
<td>325</td>
</tr>
<tr>
<td>Air cooled condenser fan consumption</td>
<td>375</td>
</tr>
<tr>
<td>Auxiliary systems</td>
<td>60</td>
</tr>
<tr>
<td>Net expected power</td>
<td>5147</td>
</tr>
</tbody>
</table>
Turboexpanders
GE Turboexpanders

Turboexpanders and generators can represent a large portion of the CAPEX for an ORC geothermal project

- GE has an extensive experience protected by more than 120 patents
- Any possible services, including generator drive applications, compressor drive applications and dynos.
- Direct drive or external gearboxes with a common oil supply system

The installed fleet ranges from 50 to 15,000 kW and the product line is standardized as follow:

<table>
<thead>
<tr>
<th>Frame</th>
<th>Shaft power (kW)</th>
<th>Expander outlet flow (m³/h)</th>
<th>Available casing ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>150 300 60 900 1500</td>
</tr>
<tr>
<td>20</td>
<td>1,600</td>
<td>4,000</td>
<td>• • • • •</td>
</tr>
<tr>
<td>25</td>
<td>2,000</td>
<td>5,500</td>
<td>• • • • •</td>
</tr>
<tr>
<td>30</td>
<td>4,800</td>
<td>9,000</td>
<td>• • • • •</td>
</tr>
<tr>
<td>40</td>
<td>6,500</td>
<td>16,000</td>
<td>• • • • •</td>
</tr>
<tr>
<td>50</td>
<td>10,000</td>
<td>25,000</td>
<td>• • • • •</td>
</tr>
<tr>
<td>60</td>
<td>15,000</td>
<td>36,000</td>
<td>• • • • •</td>
</tr>
<tr>
<td>80</td>
<td>20,000</td>
<td>45,000</td>
<td>• • • • •</td>
</tr>
<tr>
<td>100</td>
<td>25,000</td>
<td>70,000</td>
<td>• • • • •</td>
</tr>
<tr>
<td>130</td>
<td>30,000</td>
<td>100,000</td>
<td>• • • • •</td>
</tr>
<tr>
<td>160</td>
<td>40,000</td>
<td>150,000</td>
<td>• • • • •</td>
</tr>
<tr>
<td>180</td>
<td>45,000</td>
<td>200,000</td>
<td>• • • • •</td>
</tr>
</tbody>
</table>
GE Turboexpanders

Key features:

**Adjustable Inlet Guide Vanes**
A unique, patented, Inlet Guide Vane (IGV) controls the turboexpander gas flow in order to maintain high efficiency over a wide range of process conditions, eliminating the presence of blow-by valves.

**Dynamic dry gas seals**
DGS minimize buffer gas leakage. The dry gas seal can be applied in single, double or tandem configurations.

<table>
<thead>
<tr>
<th>Turbo expander - Technical specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power output (per stage)</strong></td>
</tr>
<tr>
<td><strong>Speed</strong></td>
</tr>
<tr>
<td><strong>Pressure Ratio</strong></td>
</tr>
<tr>
<td><strong>Inlet Pressure</strong></td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
</tr>
<tr>
<td><strong>Installed Base</strong></td>
</tr>
<tr>
<td><strong>Patents</strong></td>
</tr>
<tr>
<td><strong>Driving</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

All pure or mixed fluids in aggressive environments
Liquid up to 30% of weight at discharge
Maintenance & Diagnostics
Maintenance, Diagnostics & Operation support

- Protecting lifecycle performance with spare parts.
- Extending parts life with first-in-class repair technologies.
- Ensuring that the right expertise is on site with qualified Field Service Engineers.
- Optimizing expenditures through long-term maintenance simulations and CSA

- Managing issues before they become problems.
- Providing predictive warnings which enable optimized outage planning.
- Global iCenter network with 24/7 coverage, leveraging over 11 million hours of machine data.
- Partnering with customers on the journey to zero unplanned downtime.
- Big data and industrial internet
Finance Advisory Services
## Comprehensive Advisory Services

<table>
<thead>
<tr>
<th>Advisory service</th>
<th>Value proposition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital raising mandates</strong></td>
<td>Raise capital on behalf of the customer from multiple sources:</td>
</tr>
<tr>
<td></td>
<td>- ECA application &amp; process advisory</td>
</tr>
<tr>
<td></td>
<td>- Debt &amp; equity fund raising</td>
</tr>
<tr>
<td><strong>Project financial feasibility analysis</strong></td>
<td>Perform detailed analysis to assess project feasibility and bankability</td>
</tr>
<tr>
<td><strong>Capital optimisation &amp; funding strategy</strong></td>
<td>Understand customer finance requirements &amp; best solutions:</td>
</tr>
<tr>
<td></td>
<td>- OPEX vs CAPEX</td>
</tr>
<tr>
<td></td>
<td>- Funding optimization</td>
</tr>
<tr>
<td><strong>Direct Investment Structuring</strong></td>
<td>Structure and underwrite investments in customer projects:</td>
</tr>
<tr>
<td></td>
<td>- Development &amp; Permanent Capital</td>
</tr>
<tr>
<td></td>
<td>- Project and corporate structures</td>
</tr>
<tr>
<td><strong>Restructuring &amp; workouts</strong></td>
<td>Provide restructuring expertise for specific industries</td>
</tr>
<tr>
<td></td>
<td>Proactive portfolio management including workouts</td>
</tr>
<tr>
<td><strong>Market &amp; competitor intelligence</strong></td>
<td>Key competitors financing activity &amp; capabilities</td>
</tr>
<tr>
<td></td>
<td>Structuring intelligence on 3rd party transactions</td>
</tr>
</tbody>
</table>
Modular Solutions
GE Modular Solutions references

Gorgon FR9 Power Gen. Modules
GE is supplying machinery for the LNG cooling, CO2 sequestration and energy production.

- 5 MS9001E GTG Modules
- 113MW power each
- Control cab & aux. systems fully interconnected and wired
- Construction + FSNL in Avenza yard
- 48x22x28 m, 2300 tons

SeaSmart Offshore Package™
Offshore power generation module based on LM2500 or PGT25+G4.

- Complete, factory-tested package
- 24 years durability
- 100% of components integration
- Plug & play control cabinet
- All on-board auxiliaries
- 60% less cable laying
- 40% less interconnecting piping
Full EPC turn key capabilities
Plant design and EPC services

GE Oil&Gas can provide full range of engineering and project management to Customers for the success of their projects:

- Engineering feasibility and support to permitting
- Dedicated studies for emissions and noise
- Customized solutions for modular power generation sets with guarantees over time
- Optimized layout and performances
- EPC turn key services for complete plants from feasibility to operations
Other GE geothermal products
Electric submersible pumps
GE Electric Submersible Pumps

LIFT PLUS HIGH EFFICIENCY PUMPS

GE Lift PLUS multi-stage centrifugal pumps consist of rotating impellers and stationary diffusers that can be assembled in floater, compression or abrasion resistant modular configurations to meet the most demanding performance requirements.

ACE PLUS GAS HANDLING PUMPS

Developed by GE Global Research Centers, they create a homogenized solution enabling the system to handle gas content up to 75%.

DURA PLUS HIGH EFFICIENCY HIGH TEMPERATURE SUBMERSIBLE MOTORS

Three-phase, two-pole induction motors with shaped-bar technology for higher efficiency. Full Line power range 19 HP to 950 HP.

ACE PLUS GAS SEPARATORS

Natural and assisted mechanical separation of gas to be expelled into the annulus prior to reaching the pump.

VECTOR PLUS VARIABLE SPEED DRIVE

Reciprocating Compressors
GE Reciprocating Compressors

Hyper Compressor for LPDE plant
- Up to 3500 bar

API 11P High Speed Reciprocating Compressors
- Severe process conditions
- Stringent specifications
- Complete Rc to sell directly to EPC or Users
- High Reliability
- High Speed From 600 RPM to 1800 RPM
- Power Range 50 HP to 9000 HP
- Discharge Pressure Up to 7500 psi (515 bar)

API 618 Series O and H Process Compressors
- Small footprint
- Reduced weight
- Packageable
- Commercialization through packagers
- Power Range 100 to 35000 kW
- Low speed 200 to 750 RPM
- Discharge Pressure Up to 3500 bar
Air coolers
GE Air Cooled Heat Exchangers

GE has been a global leader in the fabrication of air cooled heat exchangers and steam condensers since the late 1960s.

References at more than 650 bar with H2S content as high as 18%. We have supplied more than 10,000 bundles for applications throughout the industry from upstream to hydrocarbon processing.

GE choose special, heavy-duty materials for sour gas applications such as Incoloy 825 which require specialized welding techniques.

**Cover plate configuration**
- Dirty fluids with low operating pressures.
- Ease of maintenance.
- Operating conditions up to 35 bar

**Plug box configuration**
- Welded box distributor with holes in front of each finned tube to allow cleaning and inspection.
- Up to 220 bar

**Pipe & bend configuration**
- Header made of forged pipe
- No inspection openings
- Extremely demanding pressure 650 bar.
Centrifugal Pumps
GE Water Pumps

GE Oil & Gas has a long history of proven design and manufacturing excellence for the industry’s most demanding pumping applications, including water and CO2 injection for enhanced oil recovery (EOR).

GE also owns a Pumps Centre of Excellence in Bari, Italy, including comprehensive testing facilities.

**DDHF BB5 barrel pumps**
In particular, DDHF BB5 back to back double volute pumps are designed for the most demanding onshore and offshore water-and CO2 injection applications could reach 500 bar and temperatures may hit 450° C.

**DDHM BB5 barrel pumps**
The DDHM BB5 features a continuously bladed diffuser-return channel to maximize flow range with high efficiency. They can process up to 1500 m³/h adsorbing up to 10 MW at 10000 rpm for gas turbine direct connection.

**MSN BB3 axially split pumps**
Another pump model successfully employed for water injection services is the multi-stage double-volute MSN BB3. This pump can process 320m³/h of water with high H2S content up to 350 bar.

These machines are produced with impeller diameters between 250 and 385 mm and five standard frames of: 4x11, 6x11, 6x12, 8x15 and 10x16.
Thank you
Contacts

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