REGASIFICATION PLANTS: CRYOGENIC ORC TO ENHANCE THE EFFICIENCY OF LNG TERMINALS

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SUMMARY

- INTRODUCTION
- LNG REGASSIFICATION ENERGY REQUIREMENTS
- TECHNOLOGY OVERVIEW
- CRYOGENIC ORGANIC RANKINE CYCLES
- ENERGY EFFICIENT LNG REGASIFICATION TECHNOLOGIES
- CONCLUSIONS
INTRODUCTION

LNG Value Chain

Energy Loss

1-3%

7-10%

0.1-1%

0.2-2%

Upstream

- On- & Off-Shore Field Development
- On- & Off-Shore Pipelines

Liquefaction Plant

- Gas/Liquid Treatment
- Liquefaction Units
- LNG Export Terminal
- Marine Facilities
- Floating Alternative: FLNG

LNG Transport

- Membrane Storage
- MOSS Technology

LNG Import Terminal

- Storage Tanks
- Regasification Units
- Jetty
- Marine Infrastructure
- Floating Alternative: FSRU

(REF 2015 - Source IGU World LNG Report 2015)
INTRODUCTION

LNG Regasification

- LNG Regasification is an excellent chance to diversify energy sources
- Global Regasification market continues to expand at a steady pace
- LNG supply is steadily increasing

SAIPEM REFERENCES
Designed and built:
12 LNG terminals
1 FSRU
40 LNG tanks

IGU World LNG Report 2016
- Global Regasification capacity: 757 MTPA
- Increase from 2014: 33 MTPA, +5%
- Floating Regasification: 77 MTPA, +35% yoy
INTRODUCTION

Recover Energy - Reduce Emissions

- Import Terminals pay considerable expenses for electrical power import
- Low usage, recurring seasonally, increases power cost weight on income
- Possible Carbon Tax would further increase the costs for power consumption

Saipem in cooperation with Politecnico di Milano has:

- studied possible schemes for meeting the electrical load of only a single regasification line while reducing (or eliminating) the primary energy use
- investigated the market for equipment technical feasibility and economics
LNG REGASSIFICATION ENERGY REQUIREMENTS

Thermal and Electric Power

\[ T_{SW} = 9^\circ C \]

\[ T_{NG} = 3^\circ C \]

\[ P = 63\div84 \text{ barg} \]

216,000 m³
(1,362 GWh)

LNG: 139 t/h
\[ T_{LNG} = -160 \, ^\circ C \]

2.25 MW\text{e}

16 kTPA

1.154 MTPA

Submerged Combustion Vaporizer
Heat Source: NG

CO2: 50000 tons/yr

3.85 MW\text{e}

LNG 1.154 MTPA

NG 1.138 MTPA

Open Rack Vaporizer
Heat Source: Sea Water

CO2: 12500 tons/yr

0

0

LNG 1.154 MTPA

NG 1.154 MTPA
TECHNOLOGY OVERVIEW

Energy Recovery Performances

Performance indexes

Specific Fuel Consumption (SCF) = \( \frac{\text{Equivalent NG consumption}}{\text{regasified LNG}} \) [\( \text{kg}_{\text{NG}}/\text{tons}_{\text{LNG}} \)]

\( \rightarrow 0 \)

Fuel Consumption Saving (FCS) = \( \frac{\text{Consumption} - \text{SCV or ORV consumption}}{\text{SCV or ORV consumption}} \) [%]

\( \rightarrow -100 \)

Reference Conversion Factor (Thermal to Electric) = 50%
TECHNOLOGY OVERVIEW

Energy Efficient Technologies

Direct expansion, pumping the cryogenic LNG to high pressures and expanding the regasified LNG to delivery pressures

Cogeneration, producing simultaneously electric and thermal power from burning a fraction of the regasified LNG

Gas Cycle, producing electric power from a fraction of the regasified LNG rejecting heat (thermal power) to regasify LNG

Organic Rankine Cycle (ORC), producing electric power using seawater as an energy source and rejecting heat to regasify LNG
CRYOGENIC ORGANIC RANKINE CYCLES

ORC: Plant configurations

- **Plant schemes**, employing direct contact heat exchanger prior to evaporation:
  - single condensation level cycle (left)
  - double condensation level cycle (right)

- **Single condensation level cycle** is the simplest, but allows for a considerably lower power production than the other solution, yielding a lower reduction of the SFC

- **Double condensation level cycle** operates with a pure fluid and allows the achievement of a higher efficiency, mainly thanks to a lower irreversibility in the heat exchange occurring in the LNG regasification process
ORC: Organic working fluid selection

- Organic working fluids are selected among hydrocarbons and refrigerants having:
  - an Ozone Depletion Potential (ODP) equal to zero
  - critical temperatures adequate for fluid evaporation near ambient temperature
- Global Warming Potential (GWP) and National Fire Protection Agency (NFPA) safety codes for the considered fluids have been considered too
CRYOGENIC ORGANIC RANKINE CYCLES

ORC: Fluid results for single condensation level cycles

Limiting phenomena are:
• low condensation pressure for fluids with high critical temperature
• high vapor fraction at turbine exit for fluids with low critical temperature
Positive outcomes with respect to single condensation level:
- much higher net power outputs
- much lower volume ratios for each turbine
## CRYOGENIC ORGANIC RANKINE CYCLES

### ORC: Plant configuration comparison selected fluids

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>R32 Single level</th>
<th>R41 double level</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORC power output</td>
<td>kW</td>
<td>2152.7</td>
<td>3318.8</td>
</tr>
<tr>
<td>Single line electric deficit</td>
<td>kW</td>
<td>-1101.6</td>
<td>20.6</td>
</tr>
<tr>
<td>% of regasification heat provided by ORC</td>
<td>%</td>
<td>63.74%</td>
<td>73.83%</td>
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<tr>
<td>Volume ratio in expansion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensation temperature</td>
<td>ºC</td>
<td>-45</td>
<td>-35.3</td>
</tr>
<tr>
<td>Condensation pressure</td>
<td>bar</td>
<td>1.41</td>
<td>6.8</td>
</tr>
<tr>
<td>Turbine discharge steam quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific Fuel Consumption (single line)</td>
<td>kg/t</td>
<td>1.16</td>
<td>-0.022</td>
</tr>
<tr>
<td>Specific Fuel Consumption (plant)</td>
<td>kg/t</td>
<td>3.52</td>
<td>2.34</td>
</tr>
</tbody>
</table>

- The **double condensation level cycle** allows increasing the ORC power output that is sufficient to cover the line electrical consumption with a small power surplus.

- The double condensation cycle require more expensive equipment:
  - the low temperature condenser needs suitable materials for cryogenic conditions
  - installation of two turbines, having an overall volume ratio larger than the one of the single condensation level cycle with R32
LNG Regasification Terminals play a strategic role in the energy sources diversification, with a particular emphasis in Europe.

Saipem and PoliMI have analyzed various solutions to improve the energy efficiency of Regasification Terminals: Organic Rankine Cycle (ORC) has the highest potential in terms of energy savings even in the case of cold seawater.

Several schemes, assessed with information from executed EPC projects and referenced equipment manufacturers, confirm the feasibility.
Thank you