POWER PLANT GAS CONVERSIONS

WÄRTSILÄ SPARK IGNITED GAS ENGINE (SG) CONCEPT
WÄRTSILÄ DUAL FUEL GAS ENGINE (DF) CONCEPT

CONVERSION CONCEPTS BASED ON EXISTING
WÄRTSILÄ VASA 32/32LN, WÄRTSILÄ 32 AND WÄRTSILÄ 46 POWER PLANTS
OVERVIEW OF A GAS CONVERSION

WÄRTSILÄ DEFINITION OF A GAS CONVERSION
A Wärtsilä gas conversion of an existing power plant is more than just an engine conversion. We consider all aspects from safety to reliability of the operation. Our conversion concepts follow the same latest design and engineering principles as new built gas power plants made by Wärtsilä.
Some good reasons why you should convert your Power Plant to gas operation

- Fuel flexibility
- Environmental benefits (NOx > 90% reduction, SOx > 95%)
- Reduced fuel costs
- Modernization of assets, state-of-the-art technology
- Reduced maintenance costs
Reasons for choosing Wärtsilä as your partner

• World class Project Management organization
  – References: 20 power plants (79 engines of total 720 MW)
• EPC provider
• Financing solutions
• We know your installation, your products and your needs
• Lifecycle support
• Long gas engine experience
• Guarantees
• Warranty
Gas conversion concepts

Today we have 3 concepts
- SG (Spark ignited Gas engines), mono fuel: natural gas
- DF (Dual Fuel), multiple fuel: HFO, LFO and natural gas
- GD (Gas Diesel), multiple fuel: HFO, LFO, crude, natural gas, associated gas

These concepts enable a very flexible operating window, and allow the operator to select the fuel depending on availability, price and need.

Wärtsilä gas conversions utilise
- same state-of-the-art technology as new delivered power plants
- same engine technology (parts and control) as new factory made engines
- same safety and engineering concept as new delivered power plants
POWER PLANT CONVERSION
MECHANICAL MODIFICATIONS TO AUXILIARY SYSTEMS
So what will change on my Power Plant?

The most convenient time for doing a gas conversion is when the plant (or a specific engine) is subject to a major overhaul.
Section view of a typical gas power plant

- Explosion vents (rupture discs) are installed in the existing exhaust gas ducting system in case of an exhaust gas explosion (unburned gas).
- The number and the location of the explosion vents depends on the layout of the existing power plant, typically 2-3 per generating set.
- The gas regulating unit controls the flow and pressure of natural gas supplied to the generating set. This unit is controlled by the power plant automation system.
Plan view of a typical gas power plant

- The exhaust gas ventilation unit purges the exhaust gas pipe in a 5-10 minute sequence when the generating set is stopped (part of the safety concept).
- Starting air bottle size and number of bottles will be increased for Vasa 32 based engines due to increased air consumption during start (pneumatic air starting motors).
- Cooling water system modifications are done due to more accurate temperature control and due to modifications to the existing charge air system on the engine.
- When generating sets (engines) are converted to gas operation, only parts related to gas operation (similar to factory made engines) are changed. If maintenance parts are needed, these are taken into account during the sales phase as well.
Section view of a typical gas power plant

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- The number and the location of the explosion vents depends on the layout of the existing power plant, typically 2-3 per generating set.
- The gas regulating unit controls the flow and pressure of natural gas supplied to the generating set. This unit is controlled by the power plant automation system.
- A pilot fuel system is installed with the pilot fuel pump and new fuel injectors combining the main fuel oil and pilot fuel.
Plan view of a typical gas power plant

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POWER PLANT CONVERSION
ELECTRICAL & AUTOMATION MODIFICATIONS TO AUXILIARY SYSTEMS
OVERVIEW OF TYPICAL ELECTRICAL AND AUTOMATION SYSTEM OF A POWER PLANT
Plan view of a typical control, electrical & automation room

- LV switchgear modifications are done due to new consumers, e.g. exhaust gas ventilation fan.
- DC panels are added for 24V DC power for the engine control system.
- Control panels are upgraded to latest PLC standard. New common control panels and engine control panels are installed or existing ones modified depending on the age of the system.
- New operating stations for the plant are installed. WOIS (Wärtsilä Operator’s Interface System) monitors and operates the functions of the plant and WISE (Wärtsilä Information System Environment) is the reporting/management system of the plant. If the hardware is up to date, only software changes are required.
Plan view of a typical control, electrical & automation room

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ELECTRICAL & AUTOMATION, TYPICAL GAS PLANT

- PLANT NETWORK, ETHERNET, TCP/IP, Twisted pairs
- PLC, or Remote I/O module
- Power monitoring unit, or Protection relay
- Ethernet switch
- Plant network, Ethernet, TCP/IP, Twisted pairs
- Plant network, Ethernet, TCP/IP, Fiber optics

- AVR, Automatic voltage regulator

- MOBILE WOIS (Optional)
- Remote solutions (optional)
- Hardcopy laser printer
- WOIS workstation
- WOIS workstation
- WISE workstation
- Ethernet switch

- LOCAL AUX CONTROL PANEL
- BJA011
- Engine UNIC
- Local Display
- Ethernet Gateway
- Embedded controller
- OPC data gateway

- Control Room
- CFA901
- Engine hall
- Local aux control panel
- BJA011
- CFC011
- Central control panel, enginewise section
- CFC0n1
- Central control panel, enginewise section
- CFC0

- WLAN Access point (Optional)

- August 26, 2013 Wärtsilä SG Gas Conversion Presentation

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MAIN CONTROL PANELS

Standardized control panels, yet ready for plant specific interface design (mainly Common panel)

Genset Control panel CFC0n1:
- Genset related meters (P, Q, V Ax3)
- Manual Control Interface
- Power Monitoring Unit
- Protection Relays
PLC for Genset control

Common panel CFA901:
- Synchronizing interface
- Double frequency meter
- Double voltage meter
- Synchroscope
- Mimic for single line diagram
PLC for Plant control
Wärtsilä’s own hardware and software designed for the harsh embedded environment

Same engine automation platform for Power Plants and Ship Power: **UNIC™**

Gas plant engines
- LDU Local Display Unit
- ESM Engine Safety Module
- MCM Main Controller Module
- CCM Cylinder Control Module
- IOM Input/Output Modules
- PDM Power Distribution Module
WOIS display; Control Display

Typical examples from operator, WOIS point of view

- The starting conditions are checked to be “all green” before start order is given.
- Genset breaker synchronization is automatic in synch “auto” mode.
- The start/stop sequence can be followed while the PLC controls the sequences automatically.
- Genset start and stop commands.

The request for plant operation includes:

- Active power setpoint
- Power factor setpoint

(Fuel mode selection for multi-fuel engines)
POWER PLANT CONVERSION
ENGINE MODIFICATIONS – SG CONCEPT
## Gas engine conversion portfolio – which engine types and models can be converted?

<table>
<thead>
<tr>
<th>Engine Types</th>
<th>6L</th>
<th>8L</th>
<th>9L</th>
<th>12V</th>
<th>16V</th>
<th>18V</th>
<th>20V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vasa 32 → 34SG</td>
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<td></td>
<td>(370 / 375 kW/cyl)</td>
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<tr>
<td>Wärtsilä 32 → 34SG</td>
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<td>(450 / 460 kW/cyl)</td>
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<td></td>
<td>→ standard rating</td>
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<tr>
<td></td>
<td>(480 / 500 kW/cyl)</td>
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<td></td>
<td>→ if generator allows</td>
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</tr>
<tr>
<td>Wärtsilä 46 → 50SG *)</td>
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</tr>
<tr>
<td></td>
<td>(975 kW/cyl)</td>
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<td></td>
<td>→ standard rating</td>
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<tr>
<td></td>
<td>(1045 / 1070 kW/cyl)</td>
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</tr>
<tr>
<td></td>
<td>→ if generator allows</td>
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<td></td>
</tr>
</tbody>
</table>

*) Older design platform (A, 905 kW/cyl) can not be converted to SG
### PERFORMANCE OF CONVERTED POWER PLANTS

<table>
<thead>
<tr>
<th>Existing engine → Type of conversion</th>
<th>Heat rate (kJ / kWh) Before</th>
<th>After</th>
<th>Engine power (kW / cyl) Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vasa 32 → 34SG (50 Hz)</td>
<td>8,540</td>
<td>8,290</td>
<td>375</td>
<td>345</td>
</tr>
<tr>
<td>Vasa 32 → 34SG (60 Hz)</td>
<td>8,480</td>
<td>8,290</td>
<td>370</td>
<td>330</td>
</tr>
<tr>
<td>Wärtsilä 32 → 34SG (50 Hz)</td>
<td>8,216</td>
<td>8,130</td>
<td>460</td>
<td>450</td>
</tr>
<tr>
<td>Wärtsilä 32 → 34SG (60 Hz)</td>
<td>8,216</td>
<td>8,130</td>
<td>450</td>
<td>435</td>
</tr>
<tr>
<td>Wärtsilä 46 → 50SG</td>
<td>8,100</td>
<td>7,900</td>
<td>975</td>
<td>975</td>
</tr>
</tbody>
</table>

Estimated performance figures above, installation specific performance figures can be given once needed inputs for calculations are known (ambient conditions, gas quality and pressure, etc).
Engine components to be added or replaced

- Normal maintenance parts are not part of conversion scope
- HFO/LFO equipment will be dismantled
- Only main components listed. All engine types have specific components to be added or replaced, even varying from engine to engine.
CONVERTED NUMBER OF INSTALLATIONS: 4
POWER: ~95 MW

Turkey
2 x 18V34SG (12 MW)
2006
3 x 18V50SG (55MW)

Portugal
1 x 12V34SG (4 MW)
2004

Peru
4 x 18V34SG (24 MW)
2008

NEW DELIVERED
Number of installations: 550
Power: 8300 MW  Engines: 1520  Countries: 58
Gas engine conversion portfolio – which engine types and models can be converted?

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Vasa 32 → 32DF</th>
<th>Wärtsilä 32 → 34DF</th>
<th>Wärtsilä 46 → 50DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-Cylinders</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9L</td>
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<td></td>
<td></td>
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<tr>
<td>18V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20V</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Wärtsilä46 A and B (905 kW/cyl) can not be converted to a full output DF

*) Older design platforms, Wärtsilä46 A and B (905 kW/cyl) can not be converted to a full output DF
### PERFORMANCE OF CONVERTED POWER PLANTS

<table>
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<tr>
<th>Existing engine</th>
<th>Type of conversion</th>
<th>Heat rate (kJ / kWh)</th>
<th>Engine power (kW / cyl)</th>
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<tbody>
<tr>
<td>Vasa 32</td>
<td>32DF (50 Hz)</td>
<td>Before: 8,540</td>
<td>After: 8,480</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Before: 375</td>
<td>After: 350</td>
</tr>
<tr>
<td>Vasa 32</td>
<td>32DF (60 Hz)</td>
<td>Before: 8,480</td>
<td>After: 8,480</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Before: 370</td>
<td>After: 335</td>
</tr>
<tr>
<td>Wärtsilä 32</td>
<td>34DF (50 Hz)</td>
<td>Before: 8,216</td>
<td>After: 8,433</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Before: 460</td>
<td>After: 450</td>
</tr>
<tr>
<td>Wärtsilä 32</td>
<td>34DF (60 Hz)</td>
<td>Before: 8,216</td>
<td>After: 8,433</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Before: 450</td>
<td>After: 435</td>
</tr>
<tr>
<td>Wärtsilä 46</td>
<td>50DF (50 Hz)</td>
<td>Before: 8,100</td>
<td>After: 7,930</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Before: 975</td>
<td>After: 950</td>
</tr>
<tr>
<td>Wärtsilä 46</td>
<td>50DF (60 Hz)</td>
<td>Before: 8,100</td>
<td>After: 7,880</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Before: 975</td>
<td>After: 975</td>
</tr>
</tbody>
</table>

Estimated performance figures above, installation specific performance figures can be given once needed inputs for calculations are known (ambient conditions, gas quality and pressure, etc.).
CONVERSION CONCEPT

• Same engine components as in new factory built DF engines.
• Well proven and reliable ported gas injection with pilot fuel oil concept.
• Same operating safety concept as for new power plants.
• Latest engine control and automation system (same as new power plants).
For optimum pilot and diesel fuel distribution

- Solenoid
- Main diesel needle
- Pilot diesel needle
- Main fuel nozzle
- Pilot diesel needle

ENGINE SYSTEMS - PILOT FUEL SYSTEM (2/3)
- Radial piston pump with internal fuel lubrication (engine driven on 50DF and electrical motor driven on 34DF)
- Suction throttling controlled pressure regulation
- Duplex fine filter
- Valve block with safety valve and pressure sensor
- Double walled high pressure fuel pipes
Gas mode
- Running on GAS with MDO pilot fuel injection.
- Automatic and instant trip to diesel mode in alarm situations without loss of engine power and speed.
- Automatic transfer to diesel mode on request at any load without loss of engine power and speed.
  - Automatic trip to diesel mode after 5 minutes at engine loads below 10%.

Diesel mode
- Running on HFO* or MDO with MDO pilot fuel injection.
- Automatic transfer to gas mode on request at loads below 80% without loss of engine power and speed.

* Wärtsilä 34DF & 50DF
OPERATING MODE CHANGES (2/2)

Diesel mode
HFO + MDO pilot

Gas mode
Natural gas + MDO pilot

Diesel mode
MDO + MDO pilot

Gradual transfer at any load
(duration ~ 1 hour)

Instant transfer at any load

Transfer at loads < 80% MCR
(duration ~ 2 minutes)

Gradual transfer at any load
(duration ~ 1 hour)

min. duration 30 minutes for HFO1
# Reference List – Dual Fuel Gas Conversions Status, 2012

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Country</th>
<th>Year</th>
<th>Conversion type</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almeida</td>
<td>Portugal</td>
<td>2004</td>
<td>1 x 12V32 HFO → 12V32DFc</td>
<td>Ready</td>
</tr>
<tr>
<td>Tearfil</td>
<td>Portugal</td>
<td>2005</td>
<td>1 x 12V32 HFO → 12V32DFc</td>
<td>Ready</td>
</tr>
<tr>
<td>Century Power</td>
<td>Pakistan</td>
<td>2005</td>
<td>3 x 12V32 HFO → 12V32DFc</td>
<td>Ready</td>
</tr>
<tr>
<td>Denizli</td>
<td>Turkey</td>
<td>2006</td>
<td>1 x 16V46 HFO → 16V50DF</td>
<td>Ready</td>
</tr>
<tr>
<td>Cerestar</td>
<td>Germany</td>
<td>2006</td>
<td>1 x 16V46 HFO → 16V50DF</td>
<td>Ready</td>
</tr>
<tr>
<td>Batamindo I</td>
<td>Indonesia</td>
<td>2005</td>
<td>5 x 18V32 HFO → 18V32DFc</td>
<td>Ready</td>
</tr>
<tr>
<td>Batamindo II</td>
<td>Indonesia</td>
<td>2006</td>
<td>7 x 18V32 HFO → 18V32DFc</td>
<td>Ready</td>
</tr>
<tr>
<td>Batamindo III</td>
<td>Indonesia</td>
<td>2007</td>
<td>4 x 18V32 HFO → 18V32DFc</td>
<td>Ready</td>
</tr>
<tr>
<td>Crescent Textile Mills</td>
<td>Pakistan</td>
<td>2007</td>
<td>1 x 16V32 HFO → 16V32DFc</td>
<td>Ready</td>
</tr>
<tr>
<td>Bilag</td>
<td>India</td>
<td>2007</td>
<td>1 x 18V32 HFO → 18V32DFc</td>
<td>Ready</td>
</tr>
<tr>
<td>Lucky Cement</td>
<td>Pakistan</td>
<td>2008</td>
<td>7 x 18V32 HFO → 18V32DFc</td>
<td>Ready</td>
</tr>
<tr>
<td>Lucky Cement</td>
<td>Pakistan</td>
<td>2009</td>
<td>3 x 12V46 HFO → 12V50DF</td>
<td>Ready</td>
</tr>
<tr>
<td>Cengiz</td>
<td>Turkey</td>
<td>2010</td>
<td>7 x 18V46 HFO → 18V50DF</td>
<td>Ready</td>
</tr>
</tbody>
</table>
## REFERENCE LIST – NEW GAS ENGINES

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Wärtsilä 32DF</th>
<th>Wärtsilä 50DF</th>
<th>Wärtsilä 34DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Plant engines</td>
<td>66 engines</td>
<td>84 engines</td>
<td>37 engines</td>
</tr>
<tr>
<td>Ship Power engines</td>
<td>28 engines</td>
<td>178 engines</td>
<td>22 engines</td>
</tr>
</tbody>
</table>