Bi-Fuel Conversion for High Speed Diesel Engins

Introduction

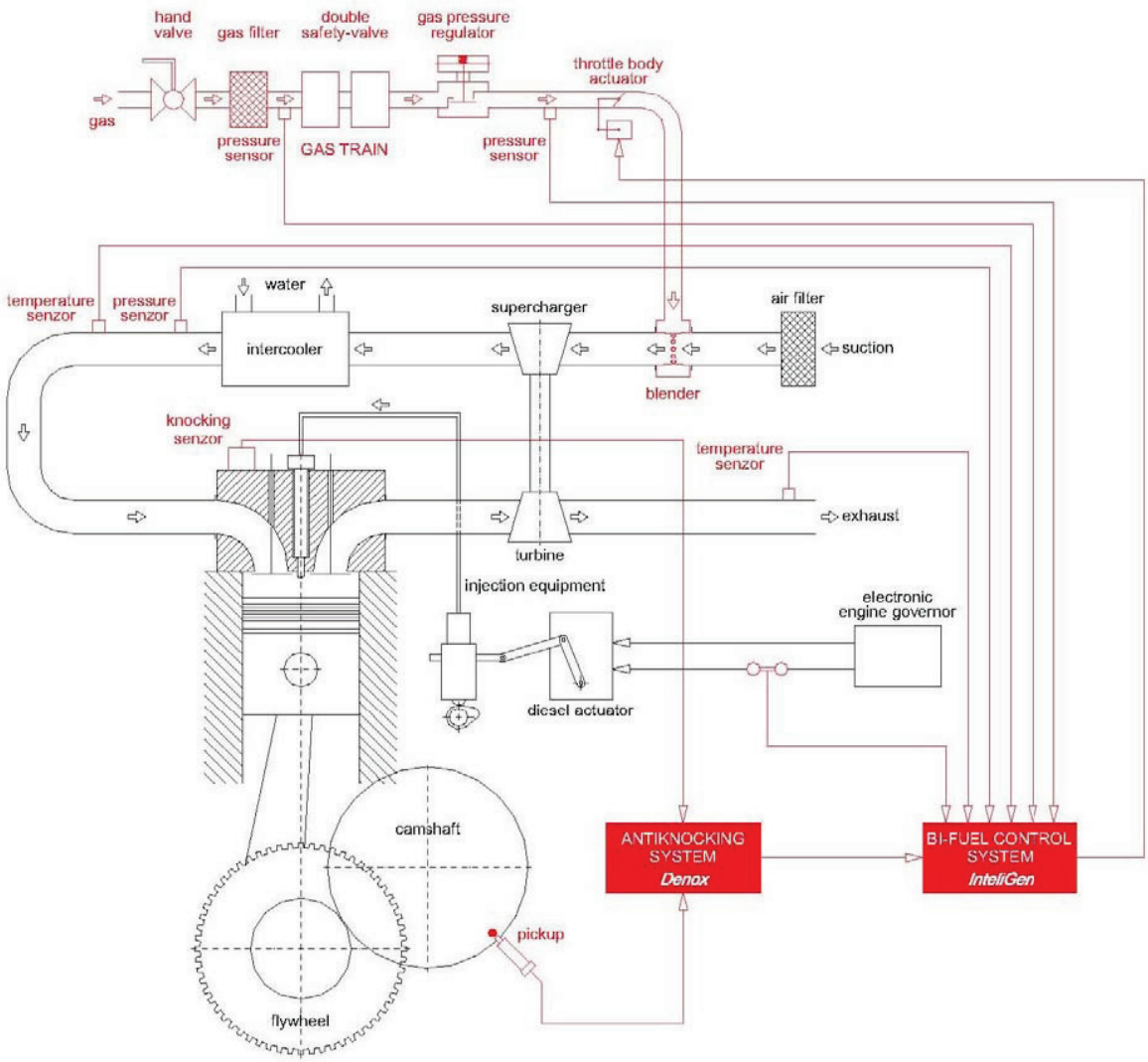
The bi-fuel system modifies standard heavy-duty diesel engines to operate on diesel and gas simultaneously. The gas is used as main fuel and the diesel is just the igniting part of the gas-air mixture. Any diesel engine with a speed range from 1200-1800 RPM can be converted and the transition between diesel and bi-fuel operation is possible at any time without interrupt of the engine power output.

By using digitally controlled throttle valve and state-of-art electronics, the system enables both safe operation and maximum utilization of gas. In most applications 50-70% of diesel can be substituted.

This document describes in detail the conversion system based on a single central gas/air mixer installed before the turbocharger, a configuration typically used for high-speed engines (1500 rpm) above 200kW.

Main features after conversion

- Substantial diesel fuel savings
- Non-derated power output of the engine
- Diesel operation available at any time Smooth transition between the modes without interruption of load supply
- The same response to load steps on bifuel as on pure diesel
- No engine modifications necessary Safe engine operation provided by state of the art electronics
- Knocking detection prevents engine damage
- Fully automatic operation
- Possibility of remote control via telephone line, GSM or internet Very efficient usage of both fuels
- Short investment payback period



The gas is introduced by the gas-air blender (venturi mixer) located after the engine inlet air filter and before the turbocharger. The amount of gas is controlled by an electrically operated gas metering valve (throttle body actuator). The gas-air mixture then flows through the intercooler and is distributed to each cylinder by the intake manifold. The mixture is then compressed in the cylinder and ignited by the injected diesel portion.

The diesel injection is controlled by the standard engine governing system during gas and diesel modes. When natural gas is introduced into the engine, the diesel governing system automatically adjusts the diesel fuel rack or injector control signal to decrease the amount of diesel fuel injected to maintain the desired engine speed. Usually there is no difference in engine performance weather an engine is operated on diesel or on bi-fuel. The engine response to load changes in bi-fuel mode is typically equal to the diesel performance. Similarly, the engine load acceptance (for large block loads) during bi-fuel operation is equal to original diesel performance.

Safe operation

The electronic control system monitors end checks various engine and system parameters such as engine load, manifold air temperature, exhaust gas temperature, gas pressures at the input and output of the gas train, diesel portion and knocking level. When any of these critical parameters exceeds the allowable limit, the control system automatically deactivates the bi-fuel operation.

a) Minimum diesel portion

The amount of diesel cannot go below ascertain minimum level, which is necessary for stable engine operation especially if cylinder misfiring has to be avoided. The control system monitors the actual amount of diesel flowing to the engine and in case the diesel is about to approach the lower limit, the system automatically decreases the gas accordingly, in order to adjust the diesel to the safe operation area.

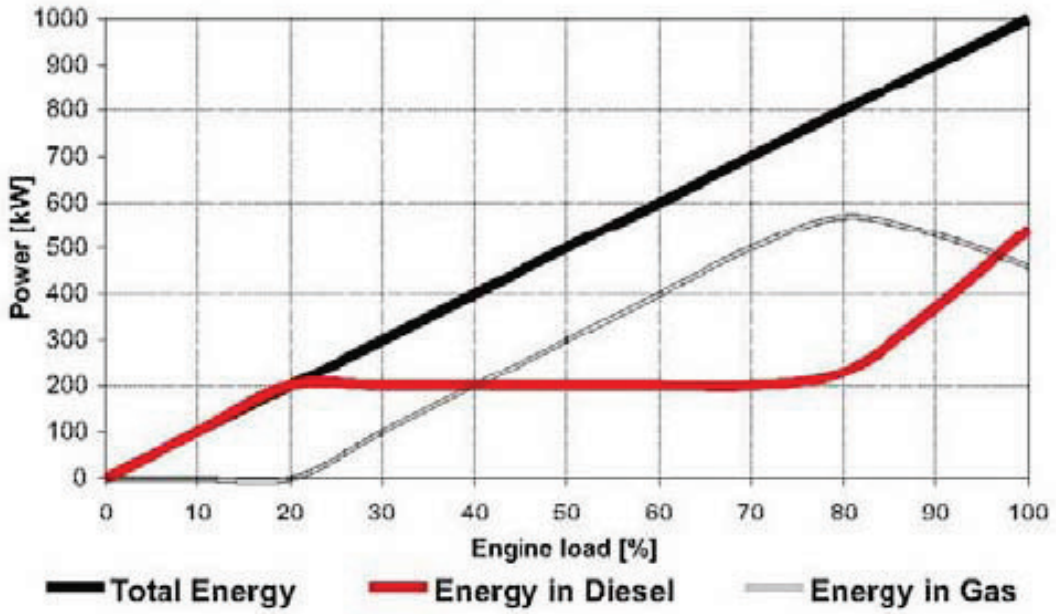
b) Engine Knocking

Proper fuel burning in the cylinder starts at the place of diesel injection and from this point the combustion gradually penetrates the rest of the combustion chamber. If pressure and temperature in the cylinder exceed a certain limit, the fuel in the combustion chamber may be self-ignited. A collision of this self-ignited pressure waves with pressure waves from the regular combustion result in sharp pressure variations. This phenomenon known as knocking is very dangerous for the engine. Sharp pressure variations act like a cavitation with the result of damage to the piston crown that may end up with piston and cylinder liner jamming.These sharp pressure variations generate structural vibrations with frequency of a few kilohertz.

The Bi-Fuel system is equipped sophisticated knocking detection system with vibration sensor on each cylinder or on each engine side. This system checks the signal from vibration structural vibrations. When the system detects knocking, the amount of gas is smoothly decreased till the detonations disappear (the gas decrease is compensated by increase of diesel).

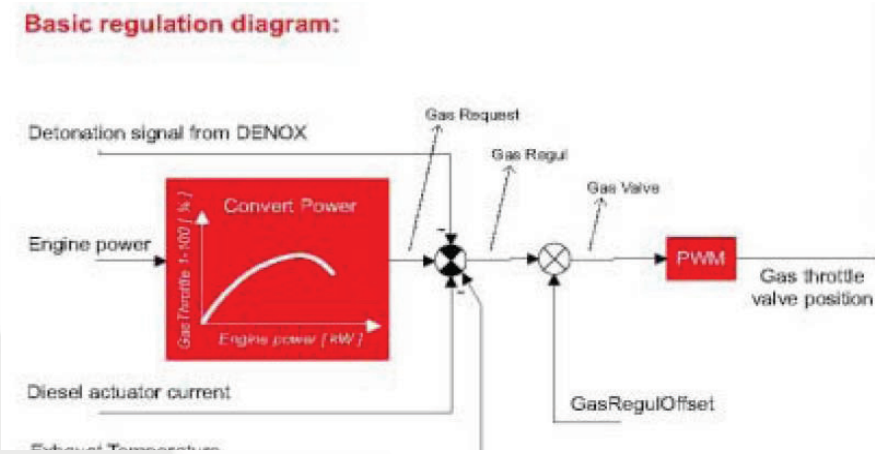
Exhaust temperature regulation

If the engine is operated in areas with rather hot climate and especially when operated on high power output (>70% of nominal load) the exhaust temperatures may raise up to the maximum temperatures stated by the engine manufacturer. Since the temperature of exhaust gases varies with the slower bi-fuel burning, temperature of ambient air, condition of turbocharger, air filter and intercooler etc., even non-linear gas mapping is not sufficient to reach optimal gas-diesel ratio. The bi-fuel system has an automatic regulation that decreases the amount of gas in case the temperature of exhaust gases exceeds an adjusted level. Exhaust gas temperatures are measured by thermocouples.



Non linear gas mapping

The amount of introduced gas is controlled by an electrically actuated throttle valve. Our dedicated bi-fuel controller uses non-linear mapping of the amount of introduced gas, depending on engine load. Non-linear mapping is necessary to achieve an optimum gas-diesel ratio for variable engine load. The graph illustrates the diesel and gas portion during the bi-fuel operation on a 1000kW engine. When the diesel portion reaches a level necessary for proper ignition (10-20% of nominal portion), the gas valve opens and covers all energy above this "ignition diesel portion". It is usually not possible to keep the diesel portion as low as20% on typical modern high-speed diesel engines for loads higher than 70 -80% of their nominal value. Usually either exhaust gas temperature rises or engine starts to knock. To avoid operation of engine in dangerous region, it is necessary to decrease the amount of delivered gas if the engine load is close to nominal load.



Major Gas Train Components

Gas train

Filtration, pressure regulation and gas conditioning are the main tasks of the gas train. The gas train consists of a filter with replaceable cartridge, manually operated valve, electrically operated double closing valves and a pressure governor. The manually operated valve is used only in case of maintenance of the system. During normal operation this valve is opened and only electrically operated valves are used for activation and deactivation of bi-fuel operation. The pressure governor uses pressure feed back for automatic compensation of pressure changes caused by fouling of inlet air filters.

Sensors

Sensors are used to maintain a safe operation of the engine: Vibration sensors, thermocouples for exhaust temperature, measurement, Sensor for inlet air temperature, Camshaft sensor.

Air/fuel mixer and throttle valve

The air-fuel mixer is used to blend the engine intake air and natural gas. Special design provides good gas-air mixing and minimum pressure drop. Since the mixer is installed upstream of the turbocharger, secondary fine mixing takes place in the turbocharger where the air and gas are perfectly mixed. The gas throttle valve is used as a gas metering device and high precision position feedback provides excellent precision of regulation of gas introduced into the engine.

Control system

The bi-fuel control system uses parts proven on hundreds of installations on diesel and gas gensets around the world.

The main controller features:

*User-friendly man machine interface with graphical screen and icons.

*Event driven log history containing all important events together with time, date and main engine parameters.

*Excellent communication capabilities providing remote monitoring by GSM or standard telephone line or Internet and easy integration to site supervision system via Modbus protocol.

*Part of the system is a knocking-detection unit.