DUAL FUEL BLENDING SOLUTION

Retrofit Case Study

October 2019.
RIJEKA, CROATIA

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ANY SITE WITH BYPRODUCT GAS CAN BENEFIT FROM DUAL FUEL BLENDING

Certain processes generate byproduct gases which can be used as additional fuel for other purposes

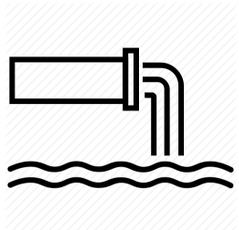
- Byproduct gases typically have large variations in pressure, flow and CH_4 content, which makes them unsuitable for applications that require precise dosing and stable combustion like gensets*
- Due to this, byproduct gases are usually burned on flares or vented to atmosphere, which is less and less acceptable.
- If used like fuel, they can generate significant savings through increased fuel efficiency.

TYPICAL INDUSTRIES FOR DUAL FUEL BLENDING APPLICATIONS

OIL & GAS

LANDFILL

WASTE WATER



DAIRY

BREWING

** equipment whose function is to convert the heat capacity into mechanical energy and then into electrical energy.*

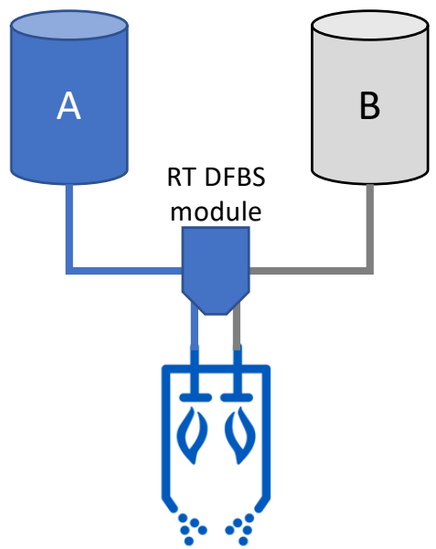
REAL-TIME DUAL FUEL BLENDING SYSTEM CAN BE USED FOR GAS TURBINES

Proper mixing of ”GOOD” and “BAD” gas in real-time can generate substantial fuel savings

- Blending two gas streams (Gas A **AND** Gas B) continuously, in real-time in order to reach and maintain optimal conditions for maximizing utilization of shaft power in prime movers such as IC gas engines or gas turbines

- Gas A should be a “good” gas with high and constant Lower Heating Value (LHV) such as:
  - Methane (CH4) from grid
  - CNG from trailers
  - LNG from grid or trailers
  - other gases with high LHV

- Gas B can be a “BAD”, byproduct gas with low LHV such as:
  - Residue from CH_4 extraction process (LHV<20MJ/Nm^3)
  - Bio gas (LHV 15MJ/Nm^3)
  - Refinery residues
  - Other gasses: IGCC systems, landfill, brewing, …



- Two models of application for real-time dual fuel blending system (RT DFBS):
  - new installation -> installing of a complete prime mover’s control and management system, including module for RT DFBS
  - on top of existing installation -> installing of module for RT DFBS, on top of original prime mover’s control and management system

TYPICAL CASES FOR REAL-TIME DUAL FUEL BLENDING SYSTEM APPLICATION

Byproduct gases with low LHV could be successfully mixed and burned

- Used for prime movers such as:
  - IC gas engines -> modified diesel or petrol engines with or without additional gas blending
  - gas turbines -> almost always with additional gas blending
- Gas characteristics:
  - very low LHV
  - composition of gas varies a lot (due to the nature of a gas derivation process, LHV could be varying a lot)
  - quantity of gas varies a lot (due to the nature of a gas derivation process, quantity at disposal could be varying a lot)
- Such gas characteristics demotivate manufactures of prime movers, so they avoid quoting such projects
- **PBM's Real-Time Dual Fuel Blending Solution has the ability to manipulate from 0-100% of each individual gas and thus:**
  - assure minimal LHV requested by the manufacturer
  - maintain LHV constant, regardless of the main gas composition or quantity
  - maintain desired electrical output, regardless of the gas quantity

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NAFTNA INDUSTRIJA SRBIJE – SERBIAN NATIONAL OIL & GAS COMPANY

Gazprom Neft is a major shareholder and operator

- NIS Group is South-East Europe's major vertically integrated power generation system
- Core business
  - exploration, extraction and refining of crude oil and natural gas,
  - sales of a wide range of petroleum and gas products,
  - delivery of petrochemical and power generation projects.
- NIS HQs and main production facilities are located in the Republic of Serbia: crude oil and gas fields, Pančevo Refinery, tank farms, refueling stations network and **14 mini power plants**
- NIS covers the entire Balkans region:
  - exploration and extraction of crude oil and gas in Romania and Bosnia-Herzegovina,
  - development of a retail network in Bulgaria, Bosnia-Herzegovina and Romania.

NIS – IMPLEMENTING THE PROGRAMME OF EFFICIENT USE OF GAS RESOURCES

14 mini cogeneration power plants installed in oil & gas fields across Serbia

15 M EUR
INVESTMENT

14.5 MW
GENERATED ELECTRICAL POWER

4 MW
GENERATED HEAT POWER

20.000
HOUSEHOLDS SUPPLIED

EFFICIENT

Gas which was flared in the past due to over 50% of the CO & N content is now used to generate electric & heat power

GREEN

considerably reduced emission of harmful gases to the atmosphere, making a significant contribution to environmental protection

NIS – PBM WAS APPROACHED TO PROVIDE DUAL FUEL BLENDING SOLUTION

on one of NIS' gas cogeneration mini power plants

PROJECT GOAL: Decrease quantity of flared gas, even if sacrificing genset output power

KEY CLIENT'S REQUIREMENTS ON DFB SOLUTION

SAFE	FLEXIBLE	SIMPLE
⚙ DFB solution should always protect engine from sudden increase in exhaust temperatures generated by dangerous gas quality fluctuations ⚙ All signals required for DFB solution should be taken from new sensors and transducers. Use of existing signals (splitting) should be avoided.	⚙ DFB solution should operate in three different modes: A) „GOOD" gas only B) „BAD" gas only C) „BLEND" mode (any ratio) ⚙ in case of mass flow valve failure, engine should be fully operable through existing „TEM EVO" system ⚙ DFB solution should be monitored both locally, and remotely	⚙ DFB solution should be easy to operate => fuel blending should run automatically, without an operator's intervention ⚙ all other „TEM EVO" functions (speed/load control, ignition control, start/stop and safety functions) should remain intact

NIS – GAS COGENERATION POWER PLANT SITE SS1 “VELEBIT”

based in Totovo selo with 4 CAT gensets, 4 MW of total power, was chosen for the pilot project

- **SITE NAME:** SS1 “VELEBIT” crude oil field
- **SITE LOCATION:** Totovo Selo, Serbia
- **SITE PURPOSE:** Gas cogeneration power plant based on 4 CAT gensets (1MW each)
- **TASK:** Implementation of Dual Fuel Blending solution on one of the gensets
- **QUICK FACTS:**
  - fuel supply - „GOOD” quality gas (Natural gas) and „BAD” quality gas (Permeate gas)
  - gensets were originally planned to run on mixture of both gases, but the system never actually worked
  - PBM engineered, installed and commissioned Real-Time Dual Fuel Blending solution based on „Woodward” E6 Fuel Blending system.

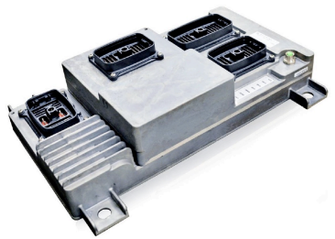
NIS – ENGINE SPECIFICATIONS AND GASEOUS FUEL CHARACTERISTICS

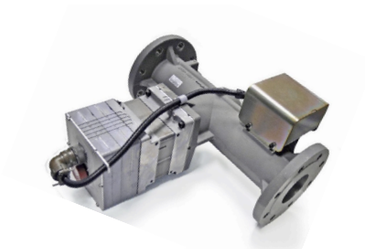
CG170-12 Gas engine

CG170-12 GAS ENGINE SPECIFICATIONS			
Type of engine:	MWM CG170-12	**Max. cont. rating (kW):**	1200 ekW
Number of cylinders:	12	**Max. cont. rating (HP):**	1610 HP
Cylinder configuration:	V	**Fuel type:**	Well gas, Bio gas, Coal gas
Engine type:	4 stroke	**Compression ratio:**	13,5:1
Displacement:	53,09 L	**Engine rotation direction:**	CW
Cylinder bore:	170mm	**Engine speed, idling:**	1500 rpm
Piston stroke:	195mm	**Maximum speed:**	1800 rpm
„GOOD" QUALITY GAS CHARACTERISTICS (Well Gas)			
Methane content (CH4%):	81-85%	**Maximum gas pressure:**	0,2 barG
Max gas flow:	517 Nm3/h	**Lower Heating Value (LHV):**	30,33 MJ/kg
Minimum gas pressure:	0,1 barG	**High Heating Value (HHV):**	32,07 MJ/kg
„BAD" QUALITY GAS CHARACTERISTICS (Production Gas/Permeate Gas)			
Methane content (CH4%):	53-65%	**Maximum gas pressure:**	0,2 barG
Max gas flow:	345 Nm3/h	**Lower Heating Value (LHV):**	18,85 MJ/kg
Minimum gas pressure:	0,1 barG	**High Heating Value (HHV):**	22,80 MJ/kg

NIS – PBM PROVIDED RT DFB SOLUTION BASED ON WOODWARD TECHNOLOGY

Woodward E6 Fuel Blending Controller and TecJet™ intelligent mass flow valves form the core of the solution





- The E6 Lean Burn Full Authority Fuel Blending control is a highly accurate, closed-loop system that maintains engine performance over a large range of fuel qualities without needing a plant-level fuel blending facility.
- The heart of the system are intelligent Woodward TecJet™ intelligent gas control valves that constantly measure mass flow of two gasses of considerably different combustion properties (natural gas with high CH_4 content & well gas with low CH_4 content).
- Information from the TecJets™ is analyzed in E6 Fuel Blending controller, which calculates perfect gas mix ratio, so that produced electric power always stays constant, even if gas quality changes.

NIS – TEST RESULTS PROVED EFFECTIVENESS AND STABILITY OF RT DFB SOLUTION

Significant changes in blending ratio ranging from 50%-85% of "BAD" gas do not change generated power or λ

MEASUREMENT #	TEST START	TEST END	BLENDING RATIO („BAD"/"GOOD" gas)	EL: POWER (KW)	„BAD" GAS FLOW (Nm3/h)	„GOOD" GAS FLOW (Nm3/h)	MEASURED λ
1	10:21	10:55	85/15 (84,8-83,8)	1041-1061	345-350	60-61	1,533-1,538
2	10:59	11:31	80/20 (80,0-80,8)	1033-1064	314-330	80-83	1,539-1,548
3	11:37	12:09	75/25 (74,4-74,8)	1030-1060	280-283	94-95	1,562-1,568
4	12:12	12:45	70/30 (69,1-69,6)	1040-1070	270-273	118-120	1,562-1,568
5	12:49	13:26	65/35 (64,9-65,1)	1033-1055	240-245	127-130	1,564-1,568
6	13:29	14:04	60/40 (60,4-60,4)	1030-1060	217-218	142-144	1,576-1,582
7	14:20	14:51	55/45 (54,2-55,8)	1033-1057	191-193	160-162	1,578-1,582
8	15:00	15:30	50/50 (49,7-50,1)	1030-1057	169-171	170-172	1,582-1,584

CHANGED **STABLE** **STABLE**

NIS – PBM'S RT DFB SOLUTION MAY GENERATE STRONG BENEFITS

Depending on a blend ratio, gas and electricity market prices, and generated el. energy use scenario

100%

decrease in flaring emissions!

1.25 mil. EUR

per year, available for other purposes!

BEFORE PBM'S DFB SOLUTION

- **BLEND RATIO BAD/GOOD:** -> 0/100
- **BAD GAS SPENT:** 0 Nm^3/h
- **GOOD GAS SPENT:** 330 Nm^3/h
- **EL. POWER GENERATED:** 1MW
- **GOOD GAS COST:** 173 EUR/h
- **EL. ENERGY REVENUE:** 81 EUR/h
- **NET OPERATING LOSS:** - 92 EUR/h

- 0.81 mil. EUR/year

AFTER PBM'S DFB SOLUTION

- **BLEND RATIO BAD/GOOD:** -> 85/15
- **BAD GAS SPENT:** 340 Nm^3/h
- **GOOD GAS SPENT:** 60 Nm^3/h
- **EL. POWER GENERATED:** 1MW
- **GOOD GAS COST:** 31 EUR/h
- **EL. ENERGY REVENUE:** -> 81 EUR/h
- **NET OPERATING PROFIT:** 50 EUR/h

+ 0.44 mil. EUR/year

** detailed savings calculation shown on the backup slide*

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OUR REAL-TIME DUAL FUEL BLENDING SOLUTION HAS PROVED EFFECTIVE

showing that byproduct gases can be successfully exploited to increase plant efficiency and protect the environment

- Byproduct gas with low LHV and varying composition and quantity could be successfully exploited by properly configured dual fuel blending system

- PBM's Real-Time Dual Fuel Blending Solution has the ability to dynamically manipulate the share of each individual gas from 0-100% and thus:
  - ensure minimal LHV requested by the manufacturer
  - maintain LHV constant, regardless of the main gas composition or quantity
  - maintain desired electrical output, regardless of the gas quantity
  - achieves blending ratio BAD GAS/GOOD GAS of 85/15 with retained and stable 1MW of power output

- **Our referent RT DFBS installation in Naftna Industrija Srbije has proved:**
  - **EFFECTIVE** -> it works reliably and keeps generated el. power stable on full output capacity
  - **EFFICIENT** -> it generates significant savings which can be redirected to other needs
  - **ENVIRONMENT-FRIENDLY** -> no more flared gas !

Check us on: **www.pbm.hr**

Ask for more information: **pbm@pbm.hr**

RIJEKA, CROATIA, OCTOBER 2019.

BACKUP SLIDE

Detailed savings calculation shown on slide 15

PLANT NET OPERATING RESULT = EL. ENERGY REVENUE – GOOD GAS COST

EL. ENERGY REVENUE = EL. ENERGY SOLD (KWh) * PRICE (EUR/KWh)

GOOD GAS COST = VOLUMETRIC FLOW (Nm^3/h) * HEAT VALUE (KWh/Nm^3) * PRICE (EUR/KWh)

BEFORE PBM'S DFB SOLUTION

EL. ENERGY REVENUE = 1000 KWh * 0,081 EUR/KWh = 81 EUR/h

GOOD GAS COST = 330Nm^3/h * 9,69 KWh/Nm^3 * 0,054 EUR/KWh = 173 EUR/h

PLANT NET OPERATING RESULT = 81 EUR/h – 173 EUR/h = -92 EUR/h

- 0.81 mil. EUR/year

AFTER PBM'S DFB SOLUTION

EL. ENERGY REVENUE = 1000 KWh * 0,081 EUR/KWh = 81 EUR/h

GOOD GAS COST = 60Nm^3/h * 9,69 KWh/Nm^3 * 0,054 EUR/KWh = 31 EUR/h

PLANT NET OPERATING RESULT = 81 EUR/h – 31 EUR/h = 50 EUR/h

0.44 mil. EUR/year

** 2019 price of natural gas in Croatia of 0,054 EUR/KWh used*
2019 price of el. energy in Croatia of 0,08 EUR/KWh used
Gas Heat Value of 9,69 KWh/Nm^3 used