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WP-3-13

FISCAL BILLING BY REAL-TIME SIMULATION

The purpose of this document is to explain how Energinet.dk uses online simulation for fiscal billing

GAS SIMULATOR

Containing the quality tracking

The quality tracking is performed by the gas simulator software "SIMONE".

The purpose of the gas simulator is to calculate the state of the transmission grid as closely as possible in all points in the grid. Hereby making estimated data available at all points in the grid at all time, e.g. flow velocities which is not measured, or data at points where no measurements are located e.g. pressure at stations without instrumentation, or **gas components and gas qualities at all offtake points**.

This last part is handled by a quality tracker inside the gas simulator, which is based on the flow velocities in the pipes.

In order to do this simulation, the Danish transmission grid is represented as a topology in the gas simulator, although slightly simplified.

The topology contains information about pipes, such as lengths and diameters throughout the grid. The topology also contains all entry and exit points, significant valves and the newly build compressor station, centrally placed in the Danish transmission grid.

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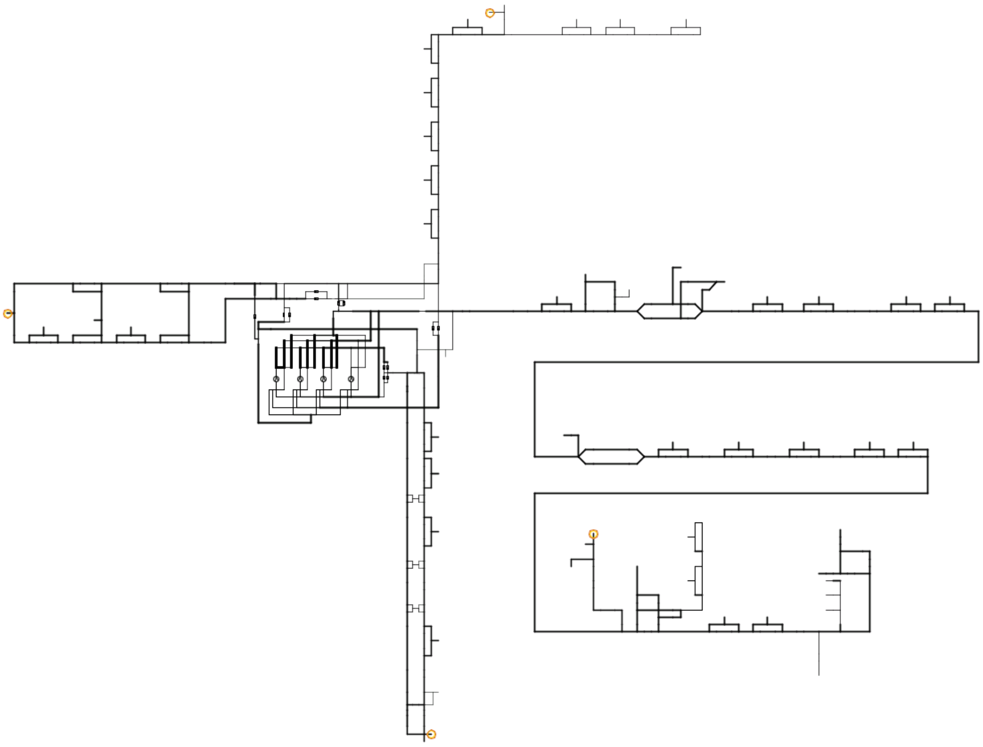

Figure 1 - Representation of the Danish transmission grid, in the gas simulator GUI

The gas simulator is closely linked to SCADA, and data is exchanged in "real time".

The primary data to achieve a correct simulation are flow and valve states. The secondary data are pressures and temperatures.

The Danish transmission grid consists of

79 stations

The Danish transmission grid consists of 79 stations and 900 km pipeline

Denmark has two delivery points for gas. Gas extracted from the offshore platforms in the North Sea, enter the Danish transmission grid at the Danish west coast, through the gas treatment facility called Nybro. The other delivery point is at the border station Ellund, between Germany and Denmark. Ellund is a combined entry and exit station.

The Danish transmission system also includes two gas storages (entry & exit stations), Lille Torup gas storage in northern Jutland, and Stenlille gas storage in Zealand, near Copenhagen.

Denmark has two exit stations, Ellund which is also an entry station, and Dragør Border where gas is exported to Sweden.

The three Danish gas distributers are supplied through 39 measurement and regulating stations.

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3 power plants are supplied with gas, directly from the Danish transmission grid.

In 2013, the first Danish compressor station was opened. The station is placed centrally in the grid, in the intersection of the North/South and East/West pipeline. The compressor station is designed as a four way station, where suction and discharge is possible in all four directions.

For safety reasons, the transmission grid also includes 31 line valve stations.

MR stations	39
LV stations	31
Border stations (entry/exit)	3
GAS storages (entry/exit)	2
Power plants	3
4-way compressor station	1

6 stations

with chromatographs

Denmark has one of the largest variations in gas quality in Europe right now. This among other things challenges the inventory of the energy amount being transported and the fiscal billing.
The flows depend on the commercial nominations from the different entry points hence the mixing of gas qualities.

All 46 exit stations are equipped with temperature, pressure and flow measurement. Of the 46 exit stations, only 5 stations are equipped with chromatographs.

The 4-way compressor station, centrally placed in the Danish transmission grid, is also equipped with chromatographs.

Figure 2 - GC locations in the Danish Transmission grid

At all other exit stations without chromatographs, we use gas simulation to estimate the gas quality for the fiscal billing. Energinet.dk uses a Real-time gas simulator, for the fiscal billing of both flow and gas quality.

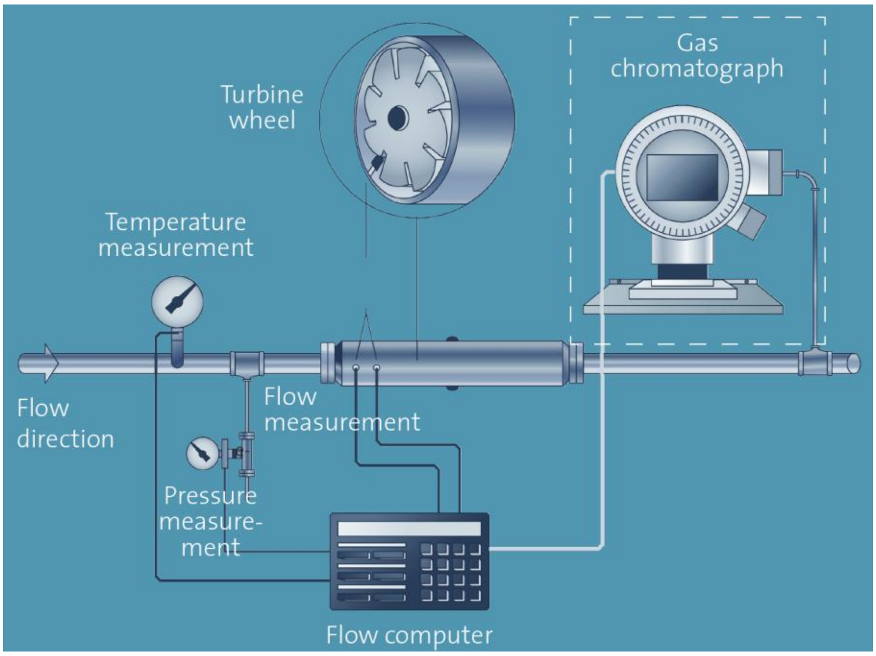

Figure 3 - Typical instrumentation in flow measurement station, with or without chromatograph.

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SCADA DATA

USED FOR SIMULATION

Data from SCADA need to be provided to the gas simulator, in order to do a simulation.

The open/close state of significant valves, are necessary to archive the correct flow of gas throughout the topology. In total, 237 valve states and 13 regulating valve states and opening percentages, are sent to the gas simulator.

Flow counter data from all entry and exit points are measured on the stations and used as input to the gas simulator.

Transmission pressure measurements throughout the grid are sent to the gas simulator, 72 in total. The pressure readings are placed with an average of 10 km apart throughout the transmission grid.

Temperature measurements on entry points are also sent to the gas simulator.

For the quality tracking, the gas chromatograph data is sent to the gas simulator. Most important are the calorific value, but also normal density, wobbe and gas components are sent to the gas simulator, and are being tracked.

Furthermore, also H_2S is tracked, to provide detailed information to the control room.

Valves	237
Regulating valves	13
Flow counters	46
Pressure measurements	72
Temperature measurements	6
H_2S	4
9 gas chromatographs	135
15 data points from each GC	

253.000 Data values

Per day (3 minute values)

The cycle time of the gas simulator is 3 minutes. With 527 data points being sent to the gas simulator per 3 minute, a total of 253.000 data values are sent to the gas simulator per day in order to track the gas quality.

In total, 560.000 simulated data values are returned to SCADA per day. The amount of simulated quality tracking data, are 338.400 data values per day.

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3 Minute cycle

Real time simulation

The SCADA system and gas simulation is based on a 3 minutes cycle, each running an individual cycle, no synchronization is performed, the cycles are based on starting full hour and continues every 3 minutes.

Every 3 minute, the following takes place:

- SCADA receives telemetered data from the stations
- SCADA calculations are executed
- Execution of gas simulation
- Simulated results are available to the control room in "real-time"
- All SCADA data, measured, calculated and simulated are stored in a historical database.

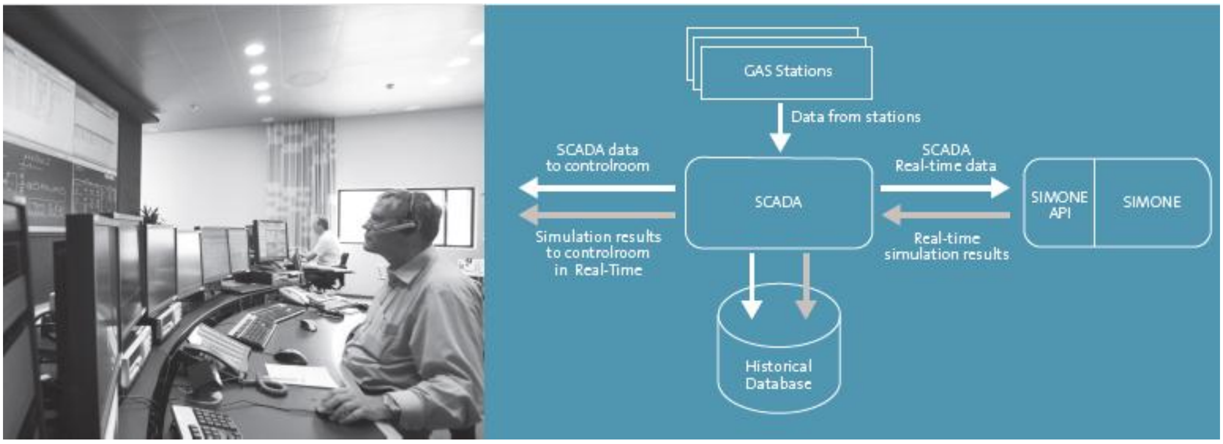

Figure 4 – Real-time data flow

<u>SCADA receives telemetered data from the stations</u>
Valve states are received by exception.
Most measurements are updated cyclic with an interval between 1 and 10 seconds throughout the 3 minutes cycle, but all flow counters are received once every 3 minutes, therefore the first 30 seconds of a cycle is reserved for collecting flow counters from the stations.

0:37 minutes into the cycle, all telemetered values, both measured and counter values, are stored to the historical database.

<u>SCADA calculations are executed</u>
From 1:00 to 1:30, all SCADA calculations are executed. The SCADA calculations includes different kinds of data quality handling, e.g. in case of lost communication to a station, the flow data is marked as BAD, and the last GOOD value are kept. The calculation also includes simple summations of e.g. individual flow strings to station sum, and unit conversion e.g. kg/h to Nm^3/h, on stations where flow is measure in kg/h.

1:30 all calculation results are stored in to the historical database.

<u>Execution of gas simulation</u>
At 1:30 in the 3 minutes cycle, the gas simulation cycle runs.
First it requests a series of data from SCADA. The SCADA system prepares the data, and the data are imported into the gas simulator.

Then the simulation is executed.

After a successful simulation, a predefined series of data are exported out of the gas simulator, and SCADA reads the data

This is expected to last less than 60 seconds.

At 2:30, all the simulation results are stored in the historical database.

<u>Simulated results are available to the control room in "real-time"</u>

At approximately 2:30 in the cycle, all the simulated data is available in the SCADA system. Some of the simulated results are shown on the SCADA displays, e.g. flow direction and velocities in pipes, estimated pressures, gas quality.

The estimated pressures, improves the overview of the grid, because of available pressure readings, where no instrumentation is located.

The estimated pressure is also compared the measured pressures. Big deviations between measured and estimated pressure, indicates a problem with the instrumentation.

GCV

Verification

The real-time results from the gas simulation are not approved for billing before a manual verification has been performed. This is normally performed each week, and the primary indication is the GCV. A chromatograph placed on the border station between Denmark and Sweden, is used to validate the results of the simulation by comparing measured GCV with the simulated GCV.

The simulated gas quality is also used to validate the chromatographs against each other.

The gas simulator can also help detect errors on flow counters or pressure transmitters.

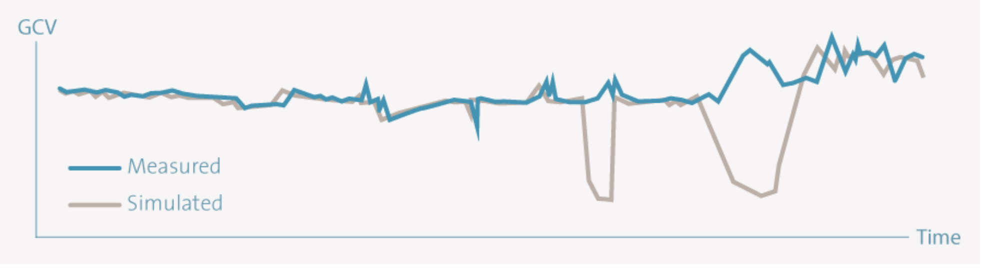

Figure 5 – Example of deviation between measured and simulated GCV before correction

If a significant deviation between measured and simulated GCV is detected at the border station, a re-simulation might be necessary, in order to achieve correct results for the fiscal billing.

On Demand

Data correction

The 3 minute cycle is running automatic, and even though an automatic data quality check is performed in the SCADA system before providing the data to the gas simulator, faulty data can be sent to the gas simulator. Therefore the real time results from the gas simulator cannot be guaranteed to be correct.

When a deviation in the simulation results is detected, the following steps are taken:

- Cause of deviation analyzed
- Data corrected in the historical database
- Re-run of gas simulation "On demand"
- Results analyzed

Cause of deviation analyzed
The simulation of the current day can be accessed, and the source data for the simulation in the historical database are analyzed.

Data corrected in the historical database
When the cause of the deviation has been found, the data is corrected in the historical database.

Re-run of gas simulation "on demand"
The gas simulation of the current day is manually re-executed.

The corrected historical data is imported into the gas simulation, the simulation is re-executed, and the new simulation results are exported into the historical database.

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This a separate interface, where the import data are taken from the historical database, opposed to the 3 minute "real-time" cycle, where the data are imported from the SCADA.

Results analyzed
The new simulation results are analyzed, to detect whether or not the deviation has been corrected.

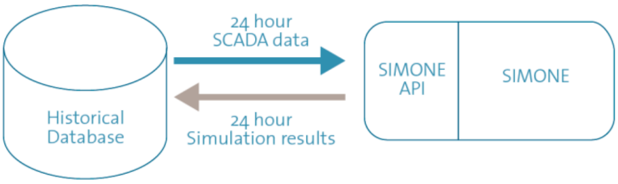

Figure 6 - On demand simulation data flow

Approval

Of simulation

After data correction we analyze the simulation one more time.

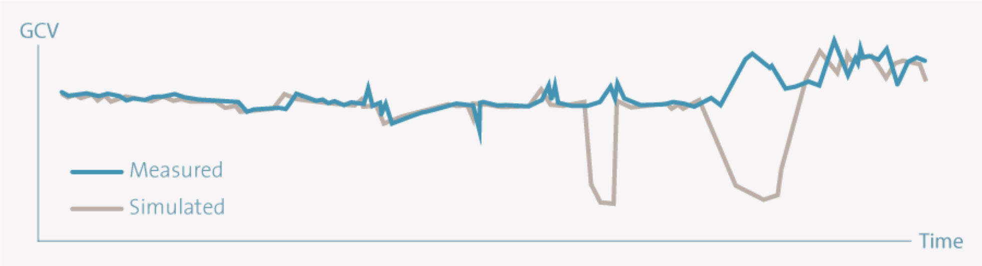

Figure 7 - Example of deviation between measured and simulated GCV before correction

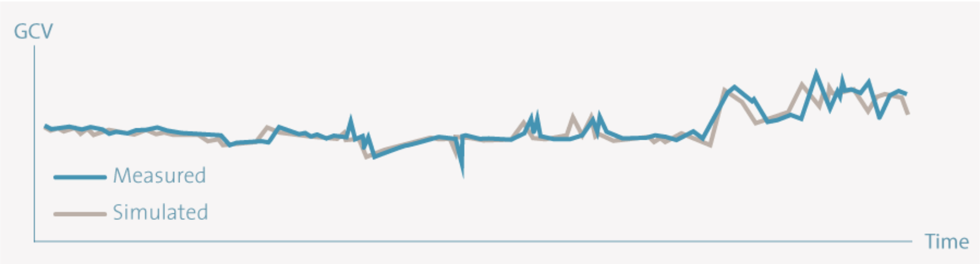

Figure 8 - GCV after correction

The use of an online gas quality tracker by both the control center and for billing purposes gives benefits but also new challenges. We only need one system and one database, however it requires more checks and traceable corrections during the month to make sure the data has sufficient quality to be used for fiscal purposes. It also requires a good cooperation between different parts of the company. The online system tracks all flows and gas qualities entering the grid and mix it.

Manual

Process

Being able to monitor the gas quality real-time, we can determine delivered energy amount at any given time on any station in the grid. We can also estimate when a given slot of gas is at a given place. We also use the output for allocation of calorific value for billing. The results are further more used by the Danish distribution companies for their billing of the consumers.

Every month we use output from the online gas quality tracker to perform retroactive corrections of flow conversion for all measurement stations using the PTZ method in the transmission grid.

We have demonstrated that billing in a grid varying gas qualities can be performed via a well-functioning on line system and a good measurement system. One depends on the other.