System Metering and Monitoring on Edvard Grieg

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Abstract

Validation of multiphase measurements may be challenging. High accuracy measurements are only possible after the fluid has undergone phase transfer, mixing and shrinkage in the processing system.

This paper will describe the model based system implemented on Edvard Grieg to monitor measurement inconsistency which shows a total overview of the field status allowing Lundin to produce closer to operating constraints.

Comparison with real data will be shown.

The described system uses a consistent fluid description that allows direct comparison of different streams. The fluid description adapts to changes in production and the system allows for continuous monitoring and tracks how imported oil and gas from Ivar Aasen affects the process and daily allocation.

1 Introduction

In general validation of multiphase measurements is a difficult task as the measurements are done at different conditions and often after processing or merging with other fluids. The high accuracy export single phase measurements are located on the export stations while lower accuracy multiphase measurements are placed closer to the wells.

1.1 Metering challenges for the Edvard Grieg production

The Edvard Grieg oil field is operated by Lundin Norway, and production began in 2015. The platform is built with a process plant which also treats the partially processed hydrocarbon stream from Ivar Aasen platform. Ivar Aasen production is mixed and processed with Edvard Grieg production before the commingled flow is measured with fiscal accuracy at export.

Comingling fluids with different ownership creates additional challenges with respect to allocation, as process shrinkage will be dependent on how the fields are produced.

The metering and allocation solution for Edvard Grieg had to meet different requirements:

- The partner agreement between Ivar Aasen and Edvard Grieg regulates how the export oil, gas, fuel, flare and gas lift are allocated between Ivar Aasen and Edvard Grieg. These rules are simple so that they can be understood and followed easily in fiscal agreements.
- Reduce financial risk related to meter unavailability by having backups and online monitoring of multiphase measurements
- Reservoir management and long term planning. For such activities simplified rules are not the best option and the input should aim to be as close as possible to what is being extracted from the reservoir.

Lundin Norway and TechnipFMC have a long running research and development cooperation, now in its fifth year, which has focused on developing new products and services related to metering and monitoring, the system installed and presented in this paper is a direct result of this cooperation.

1.2 Holistic approach to monitoring

Edvard Grieg production system uses a holistic approach to monitor measurement inconsistencies in important streams, such as well streams, fuel and flare as well as export stations. This is achieved by a system meter solution consisting of:

- An online process simulator called Overall Flow Meter Surveillance (OFMS), which allows direct comparison of well measurements with export meters and source tracking. The source tracking enables the system to calculate the contribution of all wells or owners at any stream in the topside process.
- A Virtual Flow Metering system used in well monitoring.

The system meter solution is primarily an online system, but is also possible to use as an offline simulator. The offline simulator is used for recalculating historical values. For example, after a deviation is identified, or an updated fluid characterization is available. The results can be re-exported to the data historian if needed. This is valuable as the data stored reflects the most likely historical production, and is available for re-allocation.

Virtual Flow Meters (VFM) has been in use in online metering systems for two decades, ref /1/, /2/, /3/ and is well established in the industry. In this paper, most attention is given to the OFMS.

2 The Overall Flow Metering Surveillance for Edvard Grieg

The main purposes of the Overall Flow Metering Surveillance (OFMS) is to validate the multiphase measurements by monitoring possible inconsistencies, and to keep track of the production or streams from different contributors.

The OFMS uses and online process simulator with a compositional PVT definition. Based on compositional modelling and source tracking, consistency in mass and compositional balances across the field and process is monitored. The source tracking allows the system to track contribution from a single source anywhere in the system. It is possible to calculate how much a specific well contributes to the flow at any place in the modelled process, such as lift gas. A similar system for mass balance monitoring has been described by Lundin and TechnipFMC in /4/.

Figure 1 shows a screenshot from the separator view in the OFMS.

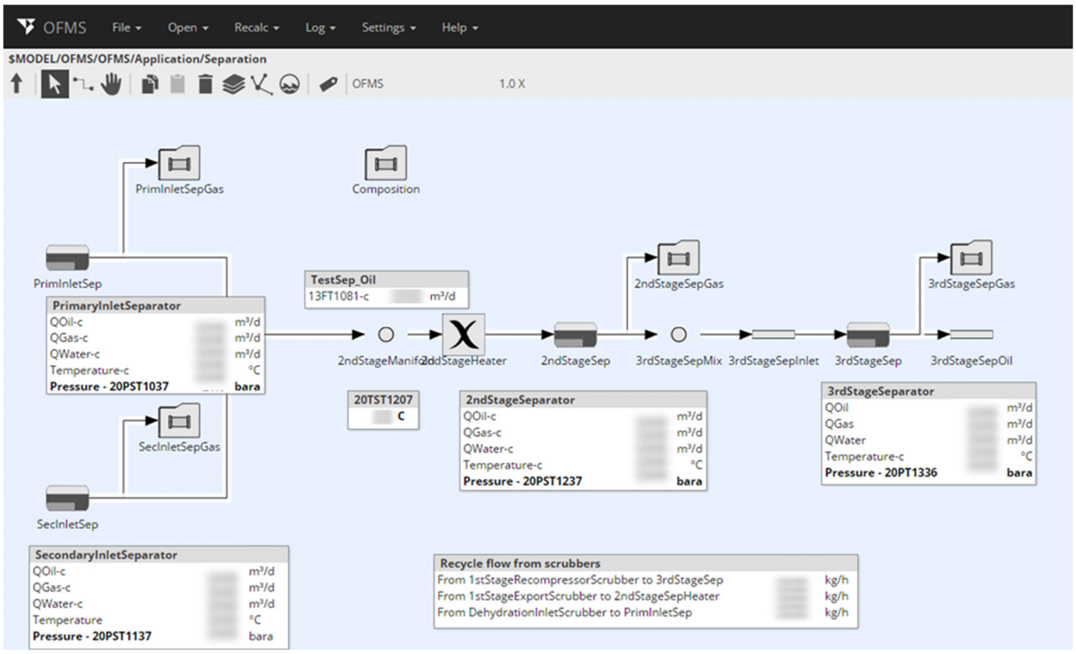

Figure 1 Screenshot from the separator view in OFMS

2.1 Model description

The system calculates the full mass and compositional balance at actual conditions through the process, this allows us to compare the calculated rates directly with export measurements where the fluids have undergone the same mixing and shrinkage.

The process model reflects a simplified version of the production system shown in Figure 2. All the separators are modelled and most of the scrubbers. The pumps and compressors are excluded from the model, instead the measured pressures and temperatures are used as input.

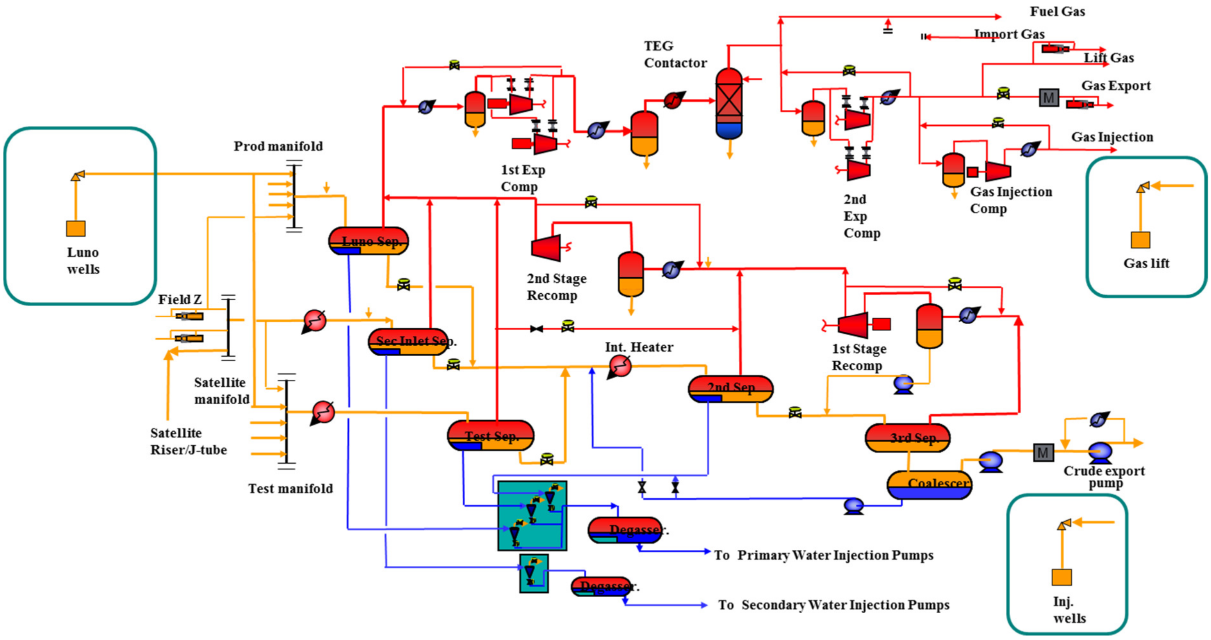

Figure 2 Edvard Grieg Topside process

The main input and output flows in the production system are illustrated in Figure 3. These are accounted for in the OFMS.

- The Edvard Grieg well rates can either be taken from the MPFM or the VFMS (Virtual Flow Meter), it is possible for the operator to choose which value to use as input individually for all wells.
- Gas lift rates, fuel and flare is also used as input. The flare meter is inaccurate and a model based backup is planned, but not implemented at the time this paper is written.
- The Ivar Aasen production can either be taken from the MPFM at the pipeline arrival at Edvard Grieg platform or the fiscal single phase meters on Ivar Aasen platform.
- The actual pressures and temperatures for the process plant also serves as input to get accurate separation.
- The output from the system is estimated gas and oil rates in addition to an estimate of the produced water.

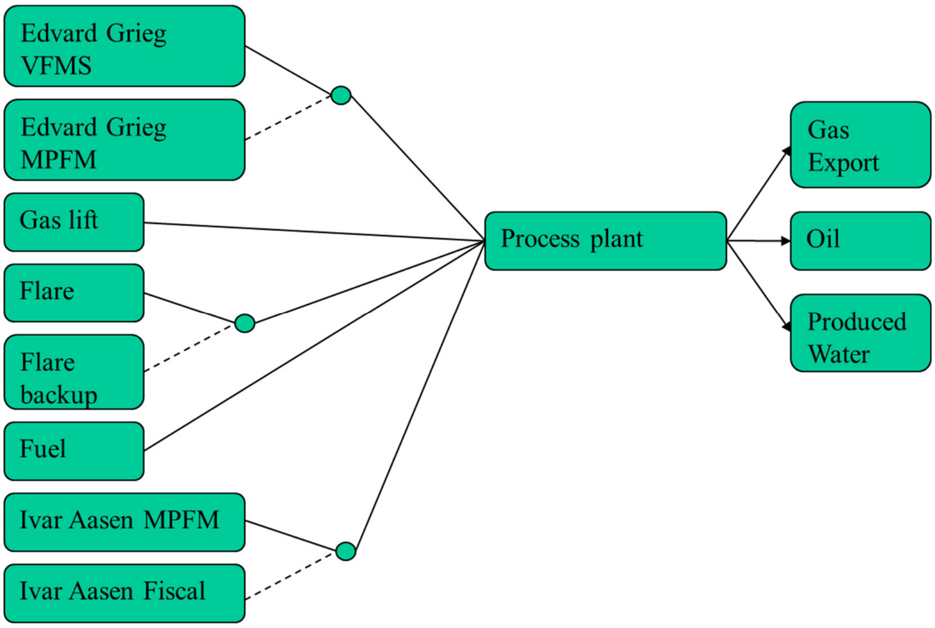

Figure 3 Overall monitoring input and output

2.2 Validation of measurements

A direct comparison between well flows and export measurements is used to determine if a significant error exists. The source tracking helps analyzing where the error most likely is coming from. Any remediation can be performed by the operator or supported by TechnipFMC service personnel.

The accuracy of the meters is in general very good, i.e. the OFMS shows a deviation within about 5% for both gas and oil, when comparing input streams to export measurements as seen in Figure 4. This comparison is possible because the OFMS includes a multistage flash simulation, and thus allows comparison of fluids at the same actual conditions. Normally such comparisons will be done by using static shrinkage factors. Such shrinkage factors are not updated with changing conditions and can lead to inaccuracies in reported production, and unnecessary corrections of metered rates due to changes in process conditions which follows comingled fluids from different sources.

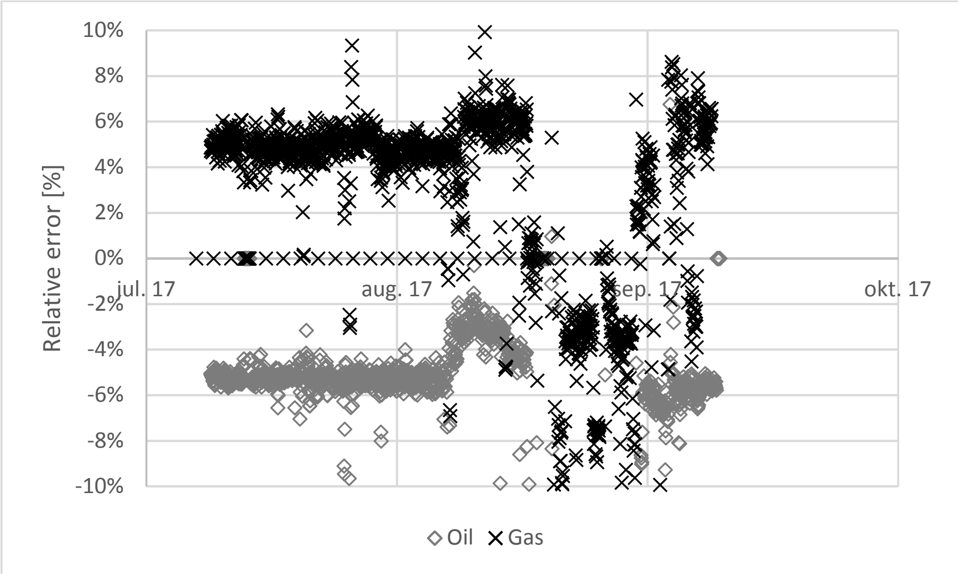

Figure 4 Relative difference between calculated export volumes and measured for oil and gas

2.3 Consistent fluid description by adaptive PVT

An adaptive PVT definition is essential to have consistency in the fluid description. The adaptive PVT is included in the OFMS for this purpose.

The adaptive PVT uses the following compositions, also shown in Figure 5, and mixes them in real time to achieve the most accurate PVT description in the process.

- Gas lift
- Reservoir gas
- Reservoir oil
- Reservoir water
- Ivar Aasen gas
- Ivar Aasen oil

The mixing is automatic, so the operator only needs to specify compositions for the Edvard Grieg- and Ivar Aasen reservoirs. The system automatically calculates and adjusts the composition from these two. The gas lift composition uses to the produced gas composition calculated by the system.

Actual pressures and temperatures from the process are used as input. Where no measurements are available, the system calculates estimated values.

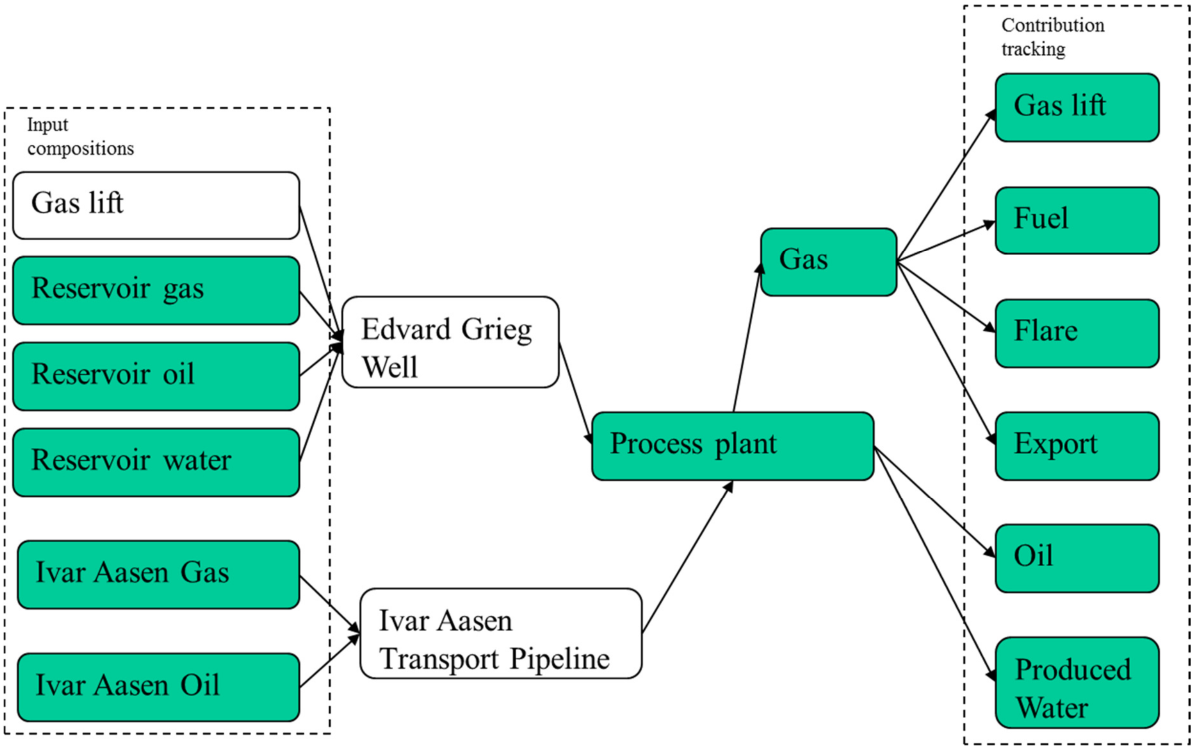

Figure 5 A simplified overview of the overall monitoring, the white boxes shows the sources, while all the boxes on the left are base compositions used by the adaptive PVT and are mixed in real time.

Figure 6 is a screenshot from the OFMS showing how the composition changes through the separation process. The left plot shows how the gas from the 3rd separation stage contains heavier components than the 2nd stage. This demonstrates the effect of the multistage flashing.

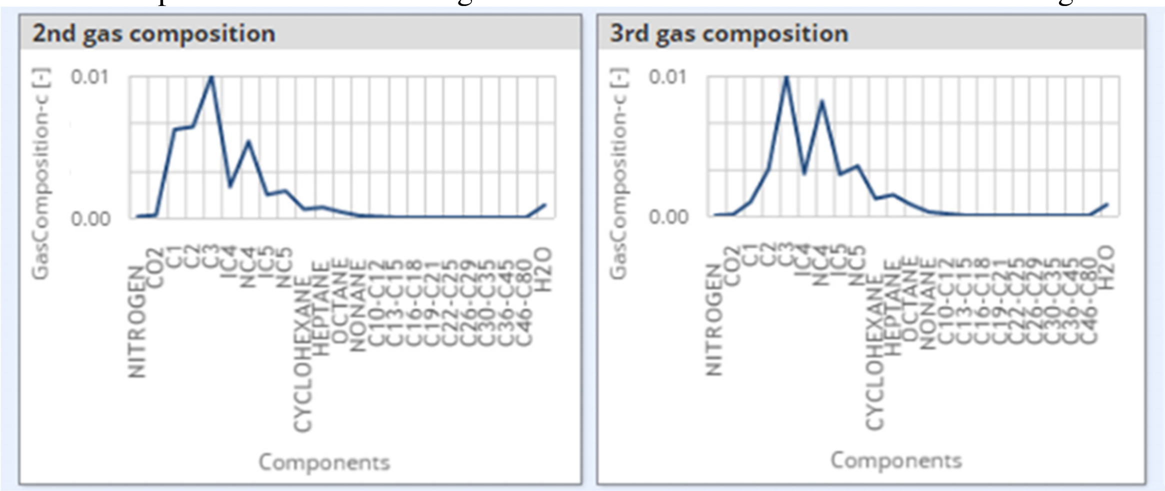

Figure 6 Screenshot from model based system, this page shows how the gas composition for 2nd and the 3rd stage in the separation, notice how the 3rd stage composition is shifted towards heavier compositions than the 2nd stage. The unit on the y-axis is mass fraction.

The adaptive PVT is validated by comparing the calculated gas composition with a gas chromatograph measurement. This is done on a component basis. The overall match is very good as seen in Figure 7, the difference corresponds to a difference in density of only 3% for gas.

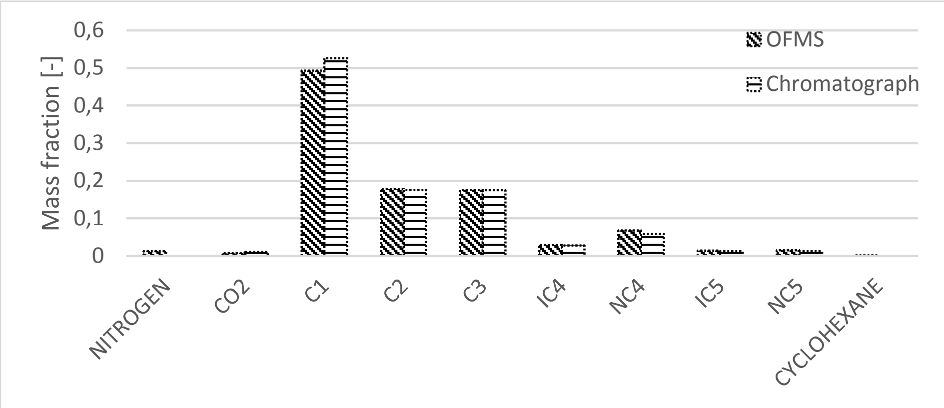

Figure 7 Comparison between OFMS and chromatograph for gas export

A large difference in compositions or density will result in a revision of the fluid compositions and description, based on the findings the OFMS would potentially have to be recalculated with an updated fluid description.

2.4 Source tracking

With the source tracking model enabled in the OFMS it is possible to calculate the contribution of Ivar Aasen and Edvard Grieg production through the system. It is also possible to calculate the contribution from single wells as well as each field. The fluids from Ivar Aasen and Edvard Grieg have different compositions and therefore the process conditions will vary with variations in the Ivar Aasen production. Source tracking is a useful tool to track the effect over time.

A principal drawing of what is accounted for in the source tracking is outlined in Figure 8. Each Edvard Grieg well has two sources, gas lift and reservoir production. Ivar Aasen production is regarded as one source in this context. The sources are shown as white boxes in Figure 5. The boxes on the right shows where it is possible to calculate the contribution by the sources.

The effect of Ivar Aasen is shown in Figure 8 where the average shrinkage factor for oil on Edvard Grieg wells is plotted together with the total volumetric flow from Ivar Aasen. The data is anonymized. The plot clearly shows how the oil shrinkage factor for Edvard Grieg wells increases with increasing Ivar Aasen production.

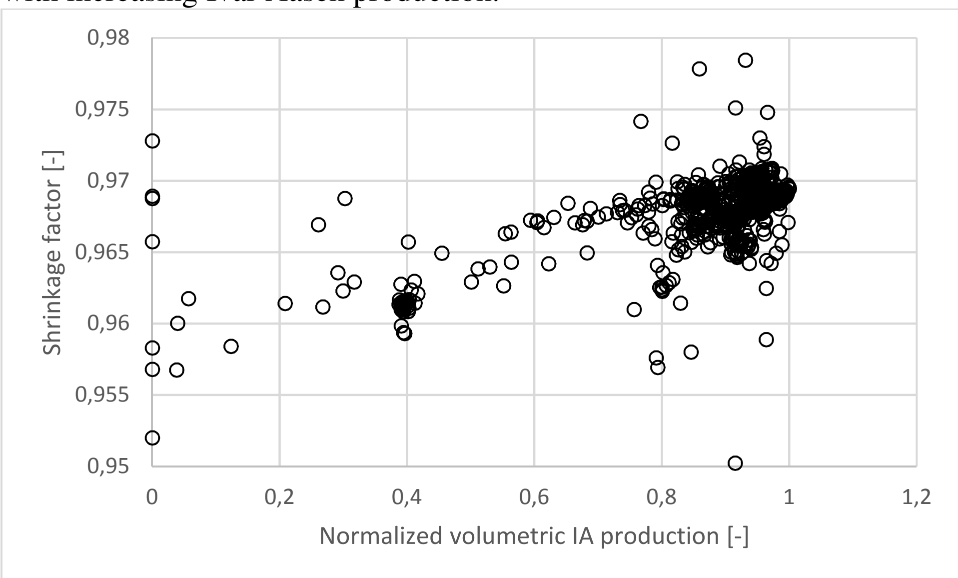

Figure 8 Average shrinkage factor for Edvard Grieg wells and normalized volumetric production from Ivar Aasen

The contribution to fuel gas is also tracked. The contribution shows a clear trend with the changing Ivar Aasen production, a change in the process or a change in reservoir output will change this contribution as well. See Figure 9. This contribution can be compared with the partner agreement, and used as input to the operator for process control.

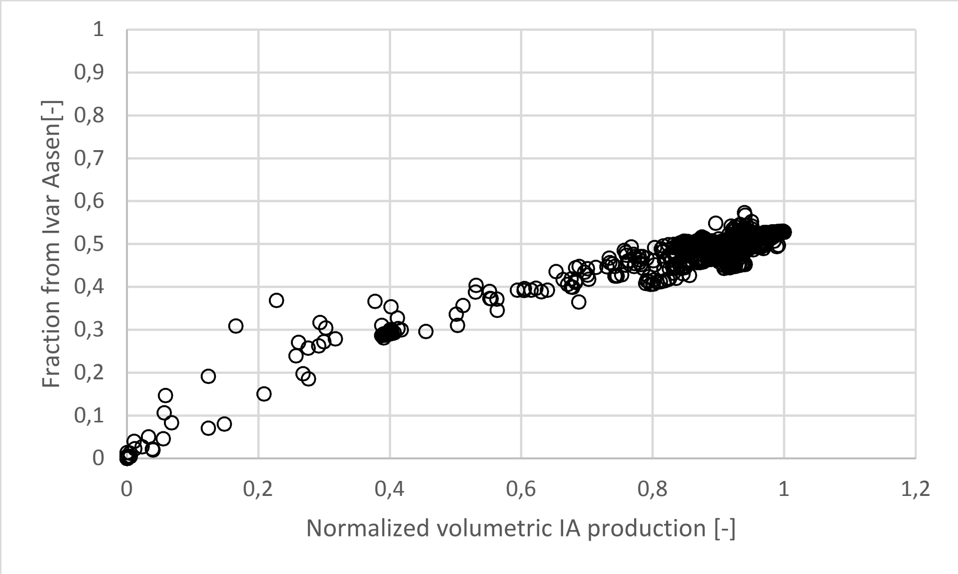

Figure 9 Ivar Aasen contribution to fuel gas as a fraction of total fuel gas mass rate and normalized volumetric production from Ivar Aasen

3 Well monitoring

The well production on Edvard Grieg is metered by MPFMs and a virtual meter used for validation and backup. The VFM is calibrated towards the test separator at actual conditions, and the PVT difference between the VFM and MPFM is monitored.

This gives a very good basis for well monitoring where two independent measurements can be verified towards each other, the test separator and towards the export meters.

When providing model based metering and monitoring of actual conditions throughout the whole production system, this gives more information than physical meters can provide independently. The combination of meters and models allows Edvard Grieg to produce closer to constraints.

An example that is actively used by the operator is a model based erosion monitoring. This is used to ensure that the velocities in the well flowlines stay within safe limits. The model based system allows the erosion monitoring to use accurate actual conditions and a consistent fluid description.

The output from the VFM serves as input to the OFMS but is also providing input to reservoir management, as the rates most closely represent what is extracted from the reservoir as they have not undergone mixing with other fluids.

4 Conclusion

The holistic approach to metering and meter surveillance on Edvard Grieg gives the operators a detailed overview of the current state of the meters and process. The VFM provides the detailed overview of wells which includes the multiphase meters and the test separator, while the OFMS allows direct comparison of the well rates with export meters. Key parameters are continuously monitored, deviations result in root cause investigations and possible calibration and recalculation of historical data to always have the most accurate information available for decision making.

The meter monitoring system is an online system that will continue to be improved, upgraded and optimized together with the field and the platform, to accommodate user needs.

The quality of the metering on Edvard Grieg is currently very good. But as the field ages problems and changes are expected to arise. The operational experience gained with a system meter monitoring tool, as described here, will be highly valuable for early detection of anomalies and deviations from normal operation, and to support identifying root causes.

5 References

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