Digester Performance Monitoring

Hitachi Zosen Inova AG (HZI) has developed Digester Performance Monitoring (DPM). It is currently being piloted at a dry anaerobic digestion plant (Kompogas® plant) to evaluate the solution's performance during live plant operation, towards the aim of commercialization in 2024.
The Kompogas® plant in Jönköping, Sweden, produces biogas from local organic waste through dry anaerobic digestion and further upgrades it into biomethane, which is then sold as fuel for CNG vehicles.

The HZI Advanced Digitalization group is developing the Digester Performance Monitoring (DPM) Digital Product which aims at improving the biological stability of Anaerobic Digestion (AD) and enables operators to run the plants at their full capacity.

Biological disruptions have been a relatively common issue in AD plants, which means that plants are not running at their full capacity and, inevitably, plant operators lose revenue during periods of process disruptions. As shown in Figure 1, currently, the biological health of digesters is monitored by performing a laboratory analysis of extracted samples of the digester which are analyzed by biotech specialists. This is a labor intensive and time-consuming process that sometimes only gives insights to a disruption when it is too late and drastic recovery measures are required, which might include reducing the throughput.

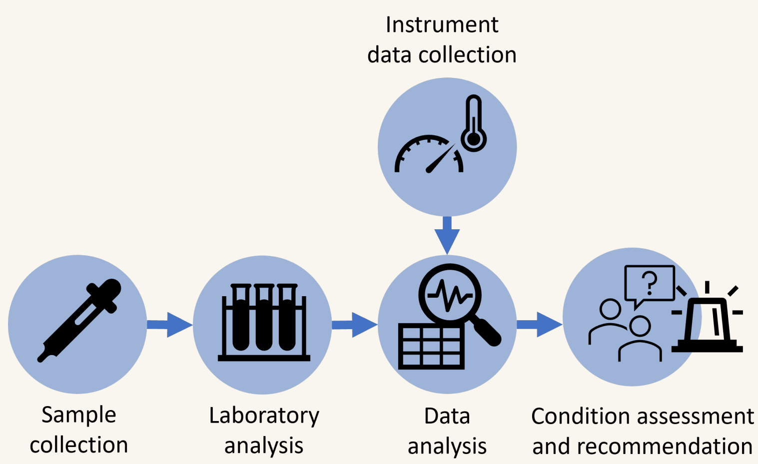

Figure 1 Current workflow to assess the biological state of the digester and provide actionable recommendations.

The DPM product relies on Machine Learning algorithms that use only a few signals from instruments that are commonly installed in AD plants and provide actionable insights to the operator. As shown in Figure 2, this new product will replace the need for lab analysis, allowing to reduce process monitoring from several days to mere seconds. AD plants will be able to run close to their biological limits, meaning that plant operators will benefit in terms of revenue.

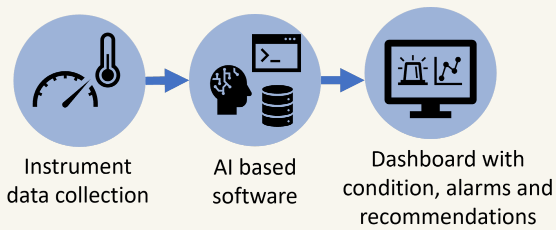

Figure 2 Workflow with the new DPM

IMPLEMENTATION

The first achieved milestone was the validation of the solution's capability of detecting biological process disruptions. For the purpose of validating the solution, the data from two AD plants was used. For each plant, a model was trained with a training data set of the correspondent plant. The model was run using the data from the validation data set and the model predictions were compared with the observed disruption events in the validation data set. Table 1 lists key parameters from the validation data set. Important requirements that the validation data set fulfilled are:

- Enough disruption events: At least five disruption events per plant with two digesters are required to complete the validation. A plant that is operated close to its biological limit has around three major disruption events per digester per year. Those five events cover the majority of yearly events which is six events for two digesters. Additionally, due to seasonality issues, at least one year of the digester operation needs to be considered for the validation. Seasonality issues arise from variations of the feedstock throughout the year, which can influence the occurrence of disruptions.

- Sufficient characterization of the data points: For each data point, the date when the digestate sample was taken and the date of the system diagnosis by a process engineer are required. Additionally, the data of the lab analysis and the recommendations given by the process engineer were used for the validation.

Table 1 Validation data set

	Plant 1	Plant 2
Daily data points	952 (2 digesters)	801 (3 digesters)
Disruptions	13	16

Figures 3 and 4 show the main validation results for 5 digesters. The main requirements for the algorithm's performance that were fully achieved are:

- All process disruptions are detected.
- Maximum of 5 false alarms per year for one digester.
- Alarm must be triggered before it is too late to start recovery measures.

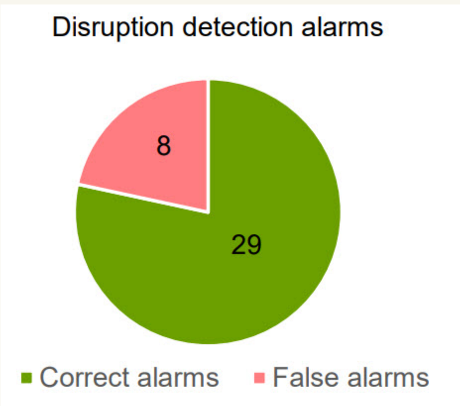

Figure 3 Disruption validation results: Correct and False alarms. There were no missed alarms.

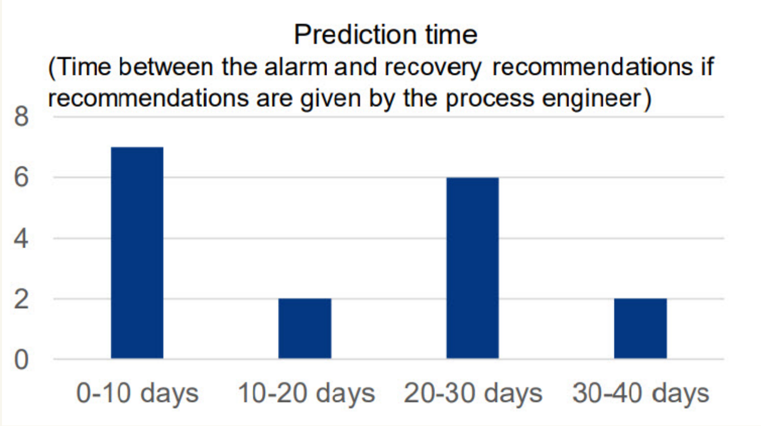

Figure 4 Disruption validation results: prediction time

PRODUCT FEATURES

Until now, samples of the digestate have been taken from each digester by a plant operator once a week and then sent off to a laboratory for testing. A lab technician produces the results, and a biotechnology expert analyses the lab data to identify any indicators that may suggest the disruption of the digester: this process typically takes several days. All in all, this means that more than a week can pass between the digester developing a problem and the detection of that problem. The longer a digester suffers from that issue, the more compromised the output biogas will be, while the disruption may last months.

The DPM product is a software solution that provides daily insights on the biological state of the digester based on signals from instruments installed in the plant. The signals are inputs for a Machine Learning model that was developed based on explainable AI principles. This brings confidence to both the developers and the biotech experts on the interpretability of the results, as the input features and the steps of the algorithm are traceable and can be mapped to process principles.

A user interface is being developed to provide an intuitive view of the digester condition, alarms and recommendations on the operation, including throughput increase when the digester condition and the feedstock allow for it. The operator is enabled to take actions to avoid disruptions and maximize the capacity of the plant. The unique features of the product are:

1. Less than 30 instruments per digestor needed.
2. High sensitivity in detecting disruptions.
3. Alarms come early enough to take action.

4. Transferability to any AD plant
5. Intuitive user interface with actionable insights

1. Less than 30 instruments per digestor are needed

Machine learning algorithms sometimes require large amounts of signals and data both during development and during operation, which has an impact on the investment and maintenance costs of such solutions. The DPM was designed to use the minimum number of signals possible and uses signals that typically exist in AD plants. This means that the applicability of this product does not require a substantial investment in instrumentation of the plant, as many plants have most (if not all) required instrumentation.

2. High sensitivity in detecting disruptions

The models of two plants have been validated and demonstrated a high sensitivity when predicting disruptions, with no missed alarms. High sensitivity can come at the cost of false alarms, but the validation results show that the number of false alarms is within the acceptable range (5 per year).

3. Alarms come early enough to take action

The validation results also demonstrated that the models predicted disruptions on average 21 days before the biotech expert was able to detect the disruption. This time frame provides enough time to apply mitigation measures, for example adjusting the feeding strategy or adding more humidification with fresh water for dilution.

4. Transferability to any AD plant

The algorithm can be transferred to any dry AD plant. Each plant requires a tailored model, with the following requirements:

- The plant specific model must be trained with the data of the new plant, but the data set does not need to contain any disruptions.
- The hyperparameters need to be adapted for each new plant due to the different substrate composition and different plant operation.

5. Intuitive user interface with actionable insights

A dashboard is being developed to provide intuitive and actionable content. As part of the ongoing pilot in the HZI operated plant in Jönköping, Sweden. The dashboard will be tested with the plant operations team to ensure that:

- The content of the dashboard is balanced: not too much information that overwhelms the users, but enough information to extract insights.
- The alarming channels (e.g. dashboard, emails) are well integrated in the workflow of the onsite team.
- The onsite team is enabled by the content and channels to autonomously extract insights and take actions.

APPROACH AND FUTURE DEVELOPMENT

The first release of the DPM product is being piloted in the HZI operated plant in Jönköping, Sweden this year, and it is foreseen to be released commercially next year. The first release features disruption alarms and an overall system check.

The second release is already in development, targeting the capability to provide automatic recommendations for mitigating disruptions, as well as increasing the throughput when the digester condition and the feedstock supply allow for it.

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