Smart Automation and Monitoring for Water Treatment in Offshore Oil and Gas Production – Challenges and Activities at AAU-ET OG Research Group

Zhenyu Yang, Associate Prof, yang@et.aau.dk

Department of Energy Technology, Aalborg University,
Esbjerg Campus, Niels Bohrs Vej 8, 6700 Esbjerg, Denmark,

This research belongs to CTR1: – Operations and Maintenance Technology

Abstract

The Produced Water (PW) is the largest produced fluid stream at most of the current offshore oil & gas production in North-sea. It is not uncommon that the water cut can reach 90% in many matured production fields. No matter whether the produced water will be eventually discharged to the ocean or reused for injection purpose in the field, the water quality needs to be strictly limited either due to the hazardous environmental impact or EOR sweeping effectiveness. For example, the current OSPAR limitation on the concentration of dispersed hydrocarbon in the discharged PW is 30 mg/l.

This poster sum up the latest activities and main achievements committed at AAU-ET OG research group, and some challenges and potentials in water treatment technologies are also pointed out.

AAU Offshore OG Testing-Rig Facility
Grey-Box Modeling of a Deoiling Hydrocyclone

Mads Valentin Bram, PhD student, mvb@et.aau.dk
Zhenyu Yang, Associate Prof (supervisor), yang@et.aau.dk

Department of Energy Technology, Aalborg University,
Esbjerg Campus, Niels Bohrs Vej 8, 6700 Esbjerg, Denmark,

This research belongs to CTR1: Operations and Maintenance Technology

Abstract

Deoiling hydrocyclones are used offshore to reduce the amount of oil in produced water that is discharged to the surrounding marine environment. Stricter regulations and environmental concerns incentivize optimization of the hydrocyclones’ deoiling performance. These requirements enforce the pursuit of better models and better controllers. This paper presents suggestions and benchmarking of a modified hydrocyclone grey-box model. The proposed model modifications relax flow conditions, such that the model errors are reduced when the system deviates from normal operation. With the aim of a more realistic model, the cylindrical underflow apex was included in the oil droplet trajectory space. An estimation of the flow that recirculates inside the hydrocyclone was introduced as this phenomenon has observed in multiple CFD models and research studies. The reduced computational load enabled the proposed model to be executed below 10ms, thus enabling the model to be used for model-based control. The original and the modified model are experimentally validated using a pilot plant. The modified model performs better during all tests and provides a reasonable prediction of deoiling separation efficiency compared with the separation efficiency obtained through real-time oil-in-water measurements.
The Influence of Parameter Variation on a Fluorescence-Based Monitor for Real-Time Measurements of Oil-in-Water Concentration

Dennis Severin Hansen – PhD student, dsh@et.aau.dk
Zhenyu Yang, Associate Prof (supervisor), yang@et.aau.dk

Department of Energy Technology, Aalborg University,
Esbjerg Campus, Niels Bohrs Vej 8, 6700 Esbjerg, Denmark,

This research belongs to CTR1: – Operations and Maintenance Technology

Abstract

Legislations of offshore facilities are currently measuring the Oil-in-Water (OiW) concentration manually before discharge, which in most cases fulfill the government regulations. However, as stricter regulations and environmental concerns are increasing every year, the importance of measuring OiW real-time incentives. The significant amount of uncertainties associated with the manual sampling could potentially affect the acceptance of OiW monitors and lower the reputation of all online OiW measurement techniques. This work presents the performance of a fluorescence-based monitor on an in-house testing facility. Previous studies of the fluorescence-based monitor have raised concerns about the measurement of OiW concentration being flow dependent. The proposed results show that the measurement from the fluorescence-based monitor is not or insignificantly flow dependent. However, other parameters such as gas bubbles, droplet sizes, quenchers of the monitor, and presences of other compositions of atomic structures in the same excitation region did affect the measurement. Thus, different parameter variations influenced the measurement of OiW, the monitors’ reproducibility was still high when accounting for the influencing parameter variations. Due to the high sensitivity to other compositions of atomic structures than aromatic hydrocarbons, the fluorescence-based monitor might not be feasible for measuring OiW concentrations in highly dynamic separations facility with consistent changes of substances in the process. Though, it might still be of interest for measuring the separation efficiency of a deoiling hydrocyclone to enhance its deoiling performance, as the separation efficiency is not dependent on OiW trueness but rather the ratio of OiW concentration before and after the hydrocyclone.
Model-Free $H_\infty$ Regulation for an Offshore Oil & Gas De-Oiling System via Off-Policy Reinforcement Learning

Shaobao Li, Petar Durdevic, Zhenyu Yang
Department of Energy Technology, Aalborg University, Esbjerg Campus, Denmark 6700

Presenting author: Shaobao Li

Is the presenting author a research assistant/MSc/PhD student/Postdoc? Yes Postdoc

Programme your research belongs to: DHRTC CTR1

Abstract:

A de-oiling system is an important facility in Oil & Gas production to separate oil from water ensuring the discharge can meet the government regulation. In industry, PID is usually used for the de-oiling system control, but it is not always effective to guarantee separation efficiency. $H_\infty$ control has been verified its effectiveness comparing with PID control in the lab. However, existing $H_\infty$ control method requires a lot of work for system identification and is difficult to transfer the $H_\infty$ control algorithm developed in lab to different industrial facilities. Towards this end, we develop a model-free $H_\infty$ regulation method using off-policy reinforcement learning (RL), where the optimal control policy is iteratively learned from measured data without requiring system identification. In the work, using game theory the classical $H_\infty$ control problem of the de-oiling system is formulated as a 2-player zero-sum game, which is normally solved by a model-based game discrete-time algebraic Riccati equation (GDARE). To solve the GDARE without using the knowledge of system dynamics, an off-policy RL algorithm for model-free $H_\infty$ regulation based on state feedback is proposed. Moreover, considering that some states such as the pressure drop rates at valves are usually not measurable, an off-policy RL algorithm for model-free $H_\infty$ regulation only using historical output measurement data is further developed. The proposed algorithm is depicted by the following diagram.
Model Predictive Control of an Offshore Separation Process

Leif Hansen, PhD student, lha@et.aau.dk
Zhenyu Yang, Associate Prof (supervisor), yang@et.aau.dk

Department of Energy Technology, Aalborg University, Esbjerg Campus, Niels Bohrs Vej 8, 6700 Esbjerg, Denmark

Programme your research belongs to: CTR1

ABSTRACT:
An optimal control solution using MPC technique is studied for a typical offshore topside separation process, which consists of an upstream three-phase separator and a downstream deoiling hydrocyclone setup. The dynamics of the separation process are described by a grey-box model combining mass balance modelling of flows and volumes with trajectory fields for the droplets. The developed MPC solution is simulated and compared with a PID controlled system. The performance of the MPC controlled system shows promising results for a solution that optimally balance the control of the separator's liquid levels and the hydrocyclone's pressure drop ratio (PDR).

Comparison of system performances subject to Current PID solution (left) and proposed MPC solution (right)
Abstract:

On-line oil in water monitors has potential to provide a better estimate of the total oil discharged for reporting, or for use as sensors for feedback control for optimization of the water treatment process. This paper presents an investigation of the potential use of a UV-fluorescence based monitor, conducted after initial attempts of implementation showed flow dependent measurements. The flow dependency was investigated through experiments during which side-stream flow was varied, while main-stream flow was kept constant and vice versa. Other influences such as air bubbles was investigated as well. It was found, that the most probable cause of the flow dependency was the appertaining changes in shearing. Increased flow rate increase shearing which in turn cause droplet breakup. The presumed breakup of larger droplets into smaller droplets could explain the increase in fluorescence due to inner filter effects. The use of side wall sampling is thought to increase this effect by taking in only the smaller droplets. In any case, if the droplet size varies significantly with changes in the process conditions the measurement could be affected, even with proper sampling. More experiments are needed to observe the actual droplet size distributions and test the current hypothesis.