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Machine learning-enabled digital twin system for evaluation of carbon footprint: A case study of offshore production assets in Nigeria

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Abstract

The emissions from offshore production assets in Nigeria require proper evaluation and quantification for efficient mitigation. The aim of this paper is to create a tool for monitoring and assessing greenhouse gas emissions in offshore oil and gas installations. The process includes acquisition of emission data from production processes and flaring. Subsequently, the development of a machine-learning enabled digital twin system to simulate the production process and flaring activities. The analysis of real-life data and simulated data will enable the prediction of future emission and devise methods for carbon footprint reduction. This work will provide oil and gas companies carrying out exploration and production to reduce green-house gas emissions and implement cleaner energy production.

Introduction

Oil and natural gas will be part of the energy system for decades to come notwithstanding ambitious efforts to reduce greenhouse gas (GHG) emissions in line with the Paris Agreement. It is therefore crucial to reduce the immediate social and environmental impacts associated with producing and consuming these fuels. The industry's operations account for nine percent of all human-made greenhouse-gas (GHG) emissions. In addition, it produces the fuels that creates another thirty-three percent of global emissions. Attention is also now increasing on the indirect emissions associated with extracting and processing oil and gas, and transporting them to consumers. Work has already been done on comprehensive global assessment of the emissions resulting from the full oil and gas supply chains for all oil and gas that is consumed today.

Indirect greenhouse gas (GHG) emissions from oil and gas operations, including both carbon dioxide and methane emissions, today are around 5 200 million tonnes (MT) of carbon-dioxide equivalent. These emissions, which do not include any emissions associated with the actual consumption of the fuel – amount to around 15% of the energy sector's total GHG emissions.

Reducing emissions from oil and gas operations

Above-ground practices, such as venting methane emissions, venting CO2 that occurs naturally alongside natural gas, and flaring of unwanted methane, rather than the type of oil or gas that is extracted, are most responsible for where different types of oil and gas fall along the spectrum. Tackling these sources of emissions offer some of the lowest-cost options to cutting energy-related emissions. Other options that have been examined to reduce these emissions include: electrifying upstream and midstream operations; installing renewable-based systems in upstream and midstream operations; equipping carbon capture, utilization and storage units at large points sources of emissions; injecting CO2 in enhanced oil recovery operations; and using low-carbon hydrogen in place of hydrogen produced using natural gas.

Significance to oil and gas industry

Countries and companies that can credibly demonstrate that they are taking action to reduce their indirect emissions could reasonably argue that these resources should be preferred over higher-emission options in a carbon-constrained world. It is crucial for the oil and gas industry to be proactive in limiting, in all ways possible, the environmental impact of oil and gas supply, and for policy makers to recognize this is a pivotal element of global energy transitions.

Aim

I intend to create a tool for monitoring and assessing greenhouse gas emissions in offshore oil and gas installations.

Objectives

The objectives of this project include:

- Collect emission data from production processes and flaring.
- Develop a machine learning-enabled digital twin system to simulate production and flaring activities and quantify emissions accurately.
- Analyze the data acquired to predict future emissions and devise best methods for carbon footprint reduction.

Literature review

A lot of work has been done on reducing emissions in the oil and gas industry. The majority of investigative papers published that analyze the possibility and potential for a renewable energy solution to the power supply of offshore platforms look at the possibilities afforded by wind power. The wide-scale and longitudinal research carried out by Wei He et al (2013) exemplify this point, as their papers recommend making large wind farms to create power for a large cluster of platforms.

There is great potential for utilizing associated natural gas which is retrieved in oil extraction. Over the years, companies such as British Petroleum have begun to exploit recent advances in technology to harness the energy found in associated gases, which is then supplied as a fuel for many offshore production platforms. Oko and Wang (2013) carbon capture in the context of carbon capture, utilization and storage (CCUS) is a great advancement in reduction of GHG emissions. Otene et al (2016) highlighted the potentials of converting flared gas from the Nigerian oil and gas industry to compressed natural gas (CNG) which could be an alternative fuel for the 220 Lagos Bus Rapid Transit (BRT-Lite) while reducing CO_2 emissions.

Knowledge gap to be filled by my research

My proposed research on machine learning enabled digital twin system for carbon footprint reduction will finesse the already existing methods and technologies proposed and implemented for GHG emission reduction with accurate quantification of emission data and predict future emissions while being used as a guide for selecting the most suitable method for emission reduction on offshore assets.

Methodology

Machine learning enabled digital twin system for evaluation of data

A digital twin is a dynamic, virtual representation of a physical asset, product, process, or system. It digitally models the properties, condition, and attributes of the real-world counterpart. Operational Digital Twins are extremely complex and challenging to create and refine. Unlike Asset Twins, they require the blending of thousands of data sources that come in myriad formats, including real-time streaming input. The only way to ingest, correlate, and integrate such diverse datasets at scale is with AI and machine learning — techniques that have only lately attained the right level of maturity for the job.

The analysis and design described herein follow a combination of system engineering processes, principles, and tools. A systems approach explores the digital twin concept in the context of Model-Based Systems Engineering (MBSE) and lightly touches aspects of Product Lifecycle Management (PLM) with focus on monitoring and assessing emissions. This thesis will employ additional methodologies such as energy road-mapping, system modeling and simulation, and case study evaluations.

Assessing and analysis of data to determine exact quantities and constituents of emitted gases

The data will be used to simulate an existing offshore production asset using an operational digital twin technology to enable me identify areas where gas emission can be reduced along the production line. It will also enable the development of improved flare stack technology to reduce the release of GHG emissions. The data used for this paper will be simulated data and real-life data from an offshore producing field.

Expected results

The project will require physical correspondence with my supervisor and outline a result-oriented path for easy execution. Extensive literature review, research and data analysis, results projection will culminate in the writing of a dissertation and presentation to an academic panel which will eventually award a doctoral degree. The positive impact of this work to the oil and gas industry in Nigeria cannot be overemphasized. It will be inculcated into undergraduate curriculums to intimate students on the unending possibilities of digital twin technologies in the oil and gas industry. More importantly, it will create a pathway for GHG emission reduction and cleaner energy production.

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