Wind-Powered Water Injection in Offshore Oil Fields

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Around one third of the global oil and gas production stems from offshore fields (Feller, 2017). Crude oil separation, gas compression and purification, wastewater treatment, seawater injection and petroleum export systems are among offshore oil production activities that consume the bulk of supplied energy and result in considerable emissions. Nearly all offshore installations generate their own electrical power by running open-cycle gas turbines to drive compressors and pumps. Approximately 80% of the CO2 and NOx emissions from offshore oil and gas installations originate from these turbines (Nord et al., 2016).

Now, the developments in offshore wind offer new opportunities for the oil industry and offshore water injection in specific. Offshore wind turbines are capable of harnessing 6MW rated power, attaining load factors upwards of 50% (Wind Europe, 2017). Building on the strength of two industries, oil & gas with wind, could enable a faster development of offshore wind turbine technologies. This paper describes the potential use of autonomous stand-alone wind turbines for exclusively powering subsea raw seawater injection facilities (zero use of gas turbines), and discusses these systems technical and economic feasibility compared to current solutions. A wind turbine would powering the subsea raw seawater injection system and no power is supplied by gas turbines.

Offshore wind powered water injection could provide a commercial and environmentally friendly alternative mean of enhancing oil recovery in deep water offshore oil fields across the globe, given that the reservoir characteristics and system design allow for raw seawater injection. The potential advantages of the proposed autonomous subsea water injection system powered by an offshore wind turbine include potentially adding oil recovery in the range of 2-20% using alternating injection rates (cyclic water injection) compared to a conventional continuous waterflood, reduction of greenhouse gas emissions and fuel costs in the offshore oil and gas industry, reduction of power transmission costs and losses compared to traditional gas powered water injection technique in cases were injection wells are located far away from the host production platform, and allowing for a faster development of offshore wind turbines technology via increased investments and research from the oil majors, as well as access to their political connections and global reach.

The main objectives of the paper are to present an optimum integrated system design for an offshore wind powered water injection process in an oil reservoir, analyse the technical and economic feasibilities of the project, and develop a preliminary screening criteria for candidate offshore oil fields based on detailed case-by-case comparison with the traditional water injection techniques. The option of dealing with intermittency of wind power generation via a cyclic or pseudo-cyclic water injection process would be investigated. A process that is based on alternated injection rates. Physical mechanism of oil recovery increase by cyclic water injection is a well-established phenomenon although the theory does not define...
the location of wells with periodical injection, amplitudes of injection variation and duration of cycles. One of the most important factors related to a cyclic waterflood, considering both wind speed variation and oil recovery enhancement, would be the ratio of injection to no-injection. An infinite amount of different cycle schemes can potentially be used. In this thesis, four schemes (injection/no injection ratios 1:1, 1:2, 1:3 and 2:1) will be tested with different cycle periods (For example 15, 30, 90 and 180 days), depending on the used wind speed data sets. Two main scenarios for water injection process in an offshore oil reservoir will be considered including continuous and cyclic water injection via simulations using a simple synthetic Eclipse 2D reservoir model over a 10 years period of cyclic injection, for execution time and better control of the physical mechanisms. For every scenarios, the injection rate, injection volume target and pressure will be optimised based on resultant maximum oil recovery. Taking the best scenarios from the 2D-model, a three dimensional case will be created for higher accuracy and better physical understanding of the process.

Following the optimisation of the water injection process and estimating power requirements, based on wind data, the wind system will be designed for the selected process. Having collected and processed the environmental data for a given location, a number of state of the art off-the-shelf 3 bladed wind turbine models including will be examined. The optimum wind turbine will be chosen based on capacity factor, AEP, and LCOE. A sensitivity study related to wind data (location wind resource and environmental conditions), wind system, offshore oil field characteristics (reservoir heterogeneity, reservoir pressure, well spacing, etc) and injection schemes would be conducted. As a conclusion to the sensitivity analysis, a screening criteria for candidate offshore projects and a corresponding optimum integrated design for the simulated cases would be concluded. Furthermore, a control system will be designed for the integrated system. At the time either the supply or load changes, the system must reliably seek to restore balance.