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Conversion Of Offshore Platform Under Decommissioning: Design And HSE Investigation Of Hydrogen Mixture Injection Plant

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The unavoidable presence of hydrogen in the fight against climate change identifies the objective of the energy transition towards a future that preserves health, safety and the environment. Its introduction encourages the development of advanced technologies, which must guarantee safety and sustainability aspects.

In this framework, the introduction of a quota of hydrogen from renewable resources into the natural gas national grid and in the temporary storages could be a successful solution to support both the decarbonisation and to respond to the challenge prompted by the European Union with the "Green Deal" set of proposals (MASE, 2024).

The hydrogen production, as energy storage, is a way to manage the unpredictability and discontinuity of renewable resources: when the offer for electricity exceeds the demand, the produced hydrogen can be introduced into the natural gas network to provide a more environmentally and economically sustainable solution. In addition, to manage the winter peak demand, the storage of the hydrogen-natural gas mixture can replace the storage of natural gas only.

Among the main types of underground gas storages, the exploitation of depleted offshore reservoirs is an interesting opportunity which, as a bonus, also avoids the decommissioning of platforms, a very long and expensive process from any point of view (economic, energetic, and environmental) involving complex operations with significant safety impacts (Li and Hu, 2023; Jácome Vidal et al., 2022; Tan et al., 2021).

The project addresses the re-use of an offshore platform in decommissioning and its depleted reservoir to install a new plant for the injection of a mixture of natural gas and hydrogen into the wells for its temporary storage.

Considering the safety issues inherent in the nature of hydrogen, a risk-based approach has been adopted for the design to guarantee the achievement of the industrial safety standards and to minimize the arising of critical or significant risks. The study presented aims at providing a guideline suitable not only for the specific case study but generally applicable.

The work was carried out in two phases. The first part deals with the conversion of an offshore hydrocarbon extraction plant into a storage site for the hydrogen–natural gas mixture (Rech, 2021). The second part, presented in the following, deals with the upstream section: the design and HSE investigation of the onshore compression station and the evaluation of the possibility to reuse the pipeline connecting the onshore to with the offshore system.

A sample-platform, named GREEN1, and its reservoir are considered as a prototype representative of most of the Italian structures. The identified design constraints are:

- the maximum pressure and flowrate of the mixture injected into and extracted from the reservoir that guarantee the operability of the plant without jeopardizing the structural integrity of the geological reservoir;
- the maximum pressure and flowrate of the mixture that can flow inside the subsea pipeline.

In consequence, the mixture flowrate fluctuates between 37600 Sm^3/h and 28222 Sm^3/h and the pressure in outlet from the onshore plant, which tends to increase as the flow decreases and vice versa, fluctuates between 40 bar to 70 bar.

As a result, all the components of the plant are assessed, namely:

- An electrolyser to produce hydrogen using renewable resources. The current percentage of hydrogen is fixed at 10% by volume of the total flow, providing a maximum needed flowrate of about 3760 Sm^3/h, meaning an installed power of about 20 MW;
- A connection to the national natural gas national grid;
- Compression units for natural gas and hydrogen to allow the two fluids to reach the same operational conditions to optimize the mixing: turbo-compressors powered by the same mixture that is operated and electro-compressors are considered the most appropriate choices to guarantee safety and availability of the plant;
- An additional compression unit dedicated to the mixture to meet the demand for pressure adjustments according to the needs;
- A heat exchanger to avoid the excessive overheating of the fluid and respect the design limits of the existing pipeline; therefore it is necessary to operate below 100°C to avoid additional stresses.

Once the most suitable components are selected and the most appropriate layout is identified, the control and safety logics to manage the plant are addressed.

The verification for the reuse of the sealine is one of the focal points of the project. On one hand, avoiding its decommissioning will produce great benefits in terms of economical investments, waste of resources, environmental damage (certainly produced during the removal) and safety issues connected to the decommissioning activities. On the other hand, the integrity of the existing pipeline may be challenged by both the aging processes and the introduction of hydrogen. Being a small molecule, it can increase the failure rate because of different damage mechanisms, among the others, the embrittlement, blistering, micro-perforation and metal hydrate formation.

For the part of the sealine above the sea and for the onshore plant, the presence of hydrogen in the mixture with respect to the base case (natural gas only) can impact not only the components failure rates but also the ignition probabilities (higher for the mixture), the expected accidental scenarios and the correspondent damage areas.

The safety analysis developed for the plant includes both a qualitative evaluation for hazard identification, through a HAZOP, and a quantitative investigation using the DNV software PHAST© to evaluate the risk and compare the consequences of natural gas and the mixture releases.

The paper describes the design process, focusing on risk assessment and safety verifications in accordance to industrial standards and best practices.

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