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UGS in giant offshore salt caverns to substitute the actual Brazilian NG storage in LNG vessels

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ABSTRACT

This paper evaluates the importance of underground natural gas storage in Brazil and the selection of an area for such, considering logistical and geomechanical aspects. Currently, the power plants are fueled by natural gas. This gas consumption is seasonal, volatile and associated with the level of rainfall in the hydroelectric power plants' basins. Therefore, Brazil has been using floating stocks of Liquefied Natural Gas (LNG) in LNG carriers. This contingency storage is inefficient and costly. This article demonstrates the technical feasibility of replacing LNG floating stocks by underground caverns created by dissolving rock salt domes offshore. Rock salt has a negligible permeability to most fluids and gasses even under high pressure. The rock salt skeleton also develops the phenomenon of creep, through which can absorb high levels of strain and can self-heal cracks and faults over time. This article also presents the design of the caverns by computer simulation. The computer codes were developed by (Costa, 1978) and (Costa, 1984), since than theses codes have been used in several different types of geomechanical engineering projects.

1. Introduction

1.1. UGS considerations

Underground hydrocarbon storage in salt caverns, opened by solution mining, has a long history of application since years 1960′s (Vassalo, 2013). Due to the first oil crises in 1974, US started the development of the Strategic Petroleum Reserve (SPR). Salt caverns were designed and developed (Schumacher, 1988). The nominal crude oil storage in the caverns is about 700.000.000 barrels. Today there is an ongoing project to increase this volume to 1 billion barrels.

The gas storage in salt caverns started in the years 1980′s (Vassalo, 2013). Today there are many sites onshore to store gas in salt caverns (Schumacher, 1988; Petersen, 1986; Heinze et al., 1994; Japel & Zipper, 1994; Laguerie & Durup, 1994). For the offshore application, there is a project called Gateway. The Gateway project plans to build 24 salt caverns in the East Irish Sea, 25 km from the coast in a water depth of 25 m. The caverns will have a working gas storage capacity of 1.52 billion standard cubic meters adding nearly 30% to the current UK gas storage capacity.

Natural gas storage in the world is designed to maintain contingency volumes of gas. Hence, it is possible to suppress the daily peak demand, or schedules, easing fluctuations of consumption. Also, there are other reasons for the use of underground spaces for storing gas (Vassalo, 2013):

- Balance the flow of gas in the pipelines to ensure that the pressure remain within the parameters of safety;
- Comply with contracts performed, keeping the scope of delivery and safeguarding any unforeseen event that may lead to fines for breach of contract;
- In temperate countries to smooth the production in periods of fluctuating consumption, storing the gas not sold immediately, usually in the summer when demand is low, and deliver it in the winter when it increases;

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- As a market speculation tool, when the producers foreseen a significant rise in the price of gas, buy gas at low prices for later when the price rise to the desired, sell;
- As insurance against unforeseen accidents, including natural disasters like hurricanes or bad functioning of production issues, etc.;
- To reduce price volatility;
- To guarantee energy supply.

The main advantages of using natural gas underground reservoirs, compared with storage in surface tanks lay on the fact that the storage volumes are significantly larger and cheaper, in addition, the careful construction and Instrumentation control leads to a significant increase in the safety of the gas storage. (Vassalo, 2013; Fabio et al., 2016; Vassalo, 2015; Costa et al., 2016; Costa et al., 2015a; Costa et al., 2015b). However, in Brazil, this practice is not yet used. The stock of natural gas (NG) in Brazil uses LNG ships and LNG regasification terminals.

The caverns opened by dissolution of salt rock have advantages compared to conventional underground spaces like aquifers and depleted reservoirs.

The more important characteristics of rock salt, which justify the storage in salt caverns are (Costa, 1984):

- The permeability is negligible to very high-pressure levels of hydrocarbons;
- The Creep Phenomenon – capable of absorbing large deformations without the development of fractures or cracks;
- The ability to absorb major variations of shear stresses through the process of creep relaxation;
- The Phenomenon of self-healing, sealing cracks developed by the excavation or pre-existing fractures;
- The Lower cost of construction and monitoring;

About the storage of natural gas, the salt caverns have the following advantages (Costa, 1984):

- It supports high rates of injection and withdrawal of gas;
- It requires smaller volume of cushion gas;
- Hermetically sealed (no fugacity);
- Additional smaller storage capacity investment.

Therefore, this study aims to verify the Brazilian potential for storing natural gas in salt caverns considering rock salt deposits at sea. It proposes and evaluates the construction, operation and geomechanical project of offshore salt caverns in Brazil to store natural gas.

This article demonstrates the technical feasibility of replacing LNG floating stocks by underground caverns created by dissolving rock salt domes offshore. It also presents the design of the caverns by computer simulation. The computer codes were developed by (Costa, 1978) and (Costa, 1984), since than theses codes have been used in the projects of conventional underground mines, several clusters of caverns for brine production, salt caverns for gas storage, soil-structure interaction of pipelines, fixed points of anchoring of offshore platforms, like torpedo piles, Vertical loading anchors and suction piles, subsea equipment, closed end pipe piles of fixed platforms and different others applications in geomechanics projects, including more than 200 oil wells crossing thick layers of stratified rock salt.

The geology section used as a reference for the generation of the geomechanical and finite element model is presented in the paper, A.M.Costa; P.V.M., Costa, C.S. Amaral, E. Poiate Jr: "Computer Modeling Applied in the Design of Salt Caverns for Natural Gas Storage", Mechanical Behavior of Salt VIII, may 26–28, 2015, publisher Taylor&Francis Group, ISBN 978-1-138-02840-1 (Costa et al., 2015b).

1.2. The importance of underground storage of natural gas in Brazil

The natural gas (NG) storage project studied in this article has two objectives. The first is to cope with the difference between NG supply and demand in Brazil, due to the use of NG in thermal power plants. The second is to act as a contingency storage to avoid shortages.

Currently, imports of Liquefied Natural Gas (LNG) compose the additional supply of Natural Gas in Brazil. To accomplish that there are three terminals: one in Pecem, in Ceara State, with import capacity of 7,000,000 m^3/day, the second in Guanabara Bay, in Rio de Janeiro, with the capacity to import of 14,000,000 m^3/day and the third in Bahia with the ability to import of 14,000,000 m^3/day (Vassalo, 2013).

The terminals can store NG in the tanks of ships: in Pecem, the ship GOLAR Spirit has the capacity of 77.4 million m^3 of NG, in Guanabara Bay the ship GOLAR Winter 82.8 million m^3 of NG and 102 million m^3 of NG in the terminal in Bahia. Therefore, the total storage capacity of NG in the tanks of ships is 262.2 million m^3.

Thermal power plants require contingent NG stocks because:

- They operate when dispatched by the "National System Operator" (NSO), only during some periods of the year. The use of NG in thermal power plants is very variable, which hinders proper planning for importing LNG;
- They should always be ready to operate, which implies there is almost immediate availability of fuel since the period between the NSO order to dispatch and the beginning of operation is less than 24 h(Vassalo, 2013);

The mismatch between the dispatch order of the NSO and the beginning of operation of thermoelectric power plants, with the deadline required to bring a cargo of LNG to Brazil of 30 days, requires the maintenance of strategic stocks of natural gas. Therefore, in average two LNG ships are used, in addition to the importation ships, to act as contingent storage(Vassalo, 2013). In some situations, when demand is less than predicted, the LNG bought in the spot market is sold at prices lower than the those used in the purchase (Costa et al., 2014).

Considering a daily demand of NG for electricity generation of approximately 50,410,958 m^3/day (Fabio et al., 2016), a contingency stock to meet the daily demand of 30 days, would be $30 \times 50{,}410{,}958$ m^3/day, namely 1,512,328,767 m^3 of NG. By subtracting this value the stock of existing NG regasification terminals, it will be necessary an additional storage of 1,250,128,767 m^3 of NG. On average, an LNG vessel carries a volume of 80,000,000 m^3 of NG at standard conditions (101.3 kPa) equivalent to 134,000 m^3 of LNG. Hence, to match this stock 16 LNG vessels would be required, as anchored off strategic stock.

In sum, the storage of NG in Salt cavern aims to replace the current time contingent on LNG vessels, with substantial reduction of cost and a significant increase in security. Besides, in the future with the increasing gas production in Brazil, owning to the new reservoirs recently found, the role of underground storage will also ensure the supply if complications occur in offshore production platforms, as well as in the NG treatment stations and NG distribution networks. Another advantage, commonly used by NG supplier companies in the United States, is the storage of gas in times of price fluctuations.