Chapter 22
Optimization of Natural Gas Liquefaction Process

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ABSTRACT

This chapter provides a brief review of the developments in the optimization of Natural gas (NG) liquefaction techniques since 2001. NG liquefaction is energy intensive and small improvements in liquefaction efficiency brings huge cost benefits thus optimization is needed. To tackle the NG liquefaction optimization problem, two different optimization philosophies, i) deterministic and ii) stochastic, have been adopted. The limitations of the deterministic approach have paved the way for derivative-free stochastic approaches. Although both techniques work well for the reported problem, their application is limited to the specific problems and generalization is quite difficult. Therefore to overcome this problem, a third of the so called knowledge-inspired class have been evolved for NG liquefaction optimization. Thus, this chapter covers the major development that took place in NG liquefaction area and after reviewing the trends future research directions are given.

INTRODUCTION

Population and income growth are the key drivers behind the growing demand for energy. By 2030, the world population is projected to reach 8.3 billion (British Petroleum, 2013), which means that an additional 1.3 billion people will require energy, and the world income in 2030 is expected to be approximately double the 2011 level in real terms. In proportion to population and income growth, world's energy consumption is projected to increase by 56% between 2010 and 2040 (U.S. Energy Information Administration, 2014). Renewable energy and nuclear power are the fastest growing sectors but fossil fuels will continue to supply 80% of the world energy until 2040 (U.S. Energy Information Administration, 2014). Among all fossil fuels, Natural Gas (NG) is the fastest growing and is increasing by 1.7% every year, primarily because of its clean burning that can meet tough environmental regulations. Recent

DOI: 10.4018/978-1-5225-0803-8.ch022

technological advances have unleased the unexplored reserves of NG thus the use of NG is seeping in every sector of human society, ranging from the basic feed stock for the manufacturing industry to household heating/cooling, transportation sector, electricity generation etc. Figure 1 presents the typical usage pattern of NG.

Under the current scenario, there are strong predictions for a significant increase in the demand for NG; as much as 30% of all fossil fuel consumption by 2040. Figure 2 shows the world energy consumption according to the fuel type and shows that the demand for NG is expected to remain strong. The strong demand for predictions of NG can be attributed to the depletion of crude oil reserves, growing environment concerns and intense competition in the global market for clean energy sources.

The world has ample proven reserves of natural gas, enough to meet the expected future demand growth. At the end of 2011, the world has enough proven reserves of NG that can meet current (2011) production levels for 64 years (British Petroleum, 2013). On the other hand, the distribution of proven reserves is not even across the world and the countries sitting on the top of 16% of the global proven gas reserves are expected to account for 38% of global production in 2030 (British Petroleum, 2013). This disproportionate share of the world's gas reserves can be compensated by innovations and improvements in energy efficiency.

Non-OECD countries rely heavily on fossil fuels to meet the growing energy demands. The world's energy related CO_2 emissions are projected to increase at 1.3% p.a between 2010 and 2040. Natural gas is expected to account for 30% of the world's fossil fuel use in 2040 but the energy related share of NG is only 22%. The enhanced energy security coupled with climate change mitigation strategies have led many countries to rely on NG.

NG is often found in remote and stranded locations and must be brought to the world market for trade. Pipeline transportation has many technical and political challenges, particularly when the gas is transported between continents. Natural gas liquefaction is another safe and economical way of bringing natural gas to the potential market. NG liquefaction reduces the volume of gas to approximately one 600^{th} of the original volume, increasing the energy density, and large quantities can be transported in the form of liquefied natural gas (LNG). LNG is an odorless, non-toxic and non-corrosive liquid that offers energy density comparable to petrol and diesel fuels. The LNG trade has increased 36% over the past 5

Figure 1. Typical usage pattern of Natural gas