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Techno-Economic Analysis of ORC in Gas Compression Stations Taking Into Account Actual Operating Conditions

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Abstract

Gas compressor stations represent a huge potential for exhaust heat recovery, currently under-exploited. Typical installations consist of multiple gas turbine units in mechanical drive arrangement, operated, most of the time, at part-load conditions and with limited conversion efficiency. In this context, this paper investigates the energetic-economic potential of ORC application in typical gas compression facilities, as innovative contribution with respect to literature. The ORC is designed to convert the gas turbines wasted heat into useful power. Additional power output can be used either inside the compression facility, reducing the amount of consumed natural gas and, consequently, the environmental impact, or delivered to the electrical grid. Taking into account real operation of gas turbines in a natural gas compression station, located in North America, additional generated energy and CO_2 avoided, thanks to ORC operation, are quantified. Two ORC arrangements, namely with and without intermediate heat transfer fluid, are proposed and the design performance are identified. Influence of topper cycle part load operations on bottomer section are quantified through an off-design thermodynamic evaluation. The goal of the performed analysis is to obtain a detailed scenario of the integrated system operation on yearly basis. Results, for a reference 50 MW compression station, show that the direct heat exchange configuration guarantees up to 66 GWh/year of additional electrical energy, saving up to $36*10^3$ tons/year of CO_2, while ORC investment costs can be recovered within 7 years of operation. The performed comprehensive investigation assesses the ORC as a techno-economic profitable technology to recover wasted heat in natural gas compression facilities.

Keywords: Organic Rankine Cycle; Gas Turbine; Natural Gas Compression station; techno-economic analiyisis; Oil&Gas Applications;

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Nomenclature

CS	Compressor Station
CHP	Combined Heat and Power
DHE	Direct Heat exchange
GT	Gas Turbine
GHG	Green House Gases emissions
HC	HydroCarbon
HE	Heat Exchanger
IHTF	Intermediate Heat Transfer Fluid
ISO	International Organization for Standardization
NG	Natural Gas
NPV	Net present value
ORC	Organic Rankine Cycle
REG	Regenerative heat exchanger
SH	Superheating

Symbols

η	efficiency [-]
I_{TOT}	Total investment costs [$]
Ma	Operating and maintenance costs [-]
n	plant assumed operating life [years]
P	power output [kW]
Q	thermal power [kW]
q	discount rate [%]
R	Revenues [$]
AVA	available

1. Introduction

A preliminary Authors investigation on Organic Rankine Cycle (ORC) energy recovery potential, in the oil&gas sector [1], showed that the Natural Gas (NG) transmission and supply network represents a significant opportunity, comparable to cement, steel and glass industries. In this context, a fundamental role is played by NG pipelines infrastructure, where Compressor Stations (CSs) are used to guarantee the gas operating pressure throughout the network. Indeed, the NG compression process requires a huge amount of energy; it is usually supplied through Gas Turbines (GTs), electric motors or reciprocated engines, working as mechanical drivers. In case of GT drivers, a small fraction of transported NG is used as fuel. In order to ensure power capability to drive compressor units, the typical installation arrangement consists of multiple GT units with a potential of operating under part-load conditions. Specifically, redundant installed capacity ensures the necessary reserve power and the safe operation of the compressors. NG fueled engines and turbines generate heat as by-product. About one third of fuel primary energy input is converted into mechanical power; the remaining two-thirds are rejected as hot exhaust and, in case of engines, also in the cooling systems. In industrial or commercial Combined Heat and Power (CHP) applications, the heat is recovered and used to provide a useful output (such as hot water or steam for the utilities). Thus, CHP applications significantly improve the overall fuel conversion efficiency of the system. On pipelines, CHP is difficult to implement: no significant thermal energy needs are accounted and CSs are located in remote places, far from industrial or urban area. As a consequence, a significant portion of primary energy is discharged into the atmosphere with exhausts. Therefore, the possibility to exploit the GT wasted heat through an ORC represents a viable solution to: (i) increase the overall efficiency of a NG CS facility; (ii) generate additional shaft power that could be used inside the compression station or, as alternative, electric power directed to the grid, (iii) reduce the pollutants emissions. A previous review study of the Authors, on European Market, in [1] estimated that the electric power recovery potential of ORC applied to CSs is close to 1300 MW, energy generation is up to 10.43 TWh per year, avoided GHG emissions up to 3.7 million tons and avoided energy costs up to 934 million euro per year.

Several studies highlighted the main advantage of ORC compared to traditional steam cycle architecture, also addressing this bottomer technology as a performing solution for both low/medium and high/medium grade wasted heat applications [1-17]. Among organic fluids suitable for GTs and internal combustion engine exhaust gases