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Grey Box Model of CO2 Refrigeration System for Heat Recovery Analysis

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Extended Abstract

CO2 refrigeration systems for supermarkets are gaining popularity in Europe, even in warmer climates. This is primarily due to stricter environmental regulations [1]. One positive aspect is that the transcritical cycle allows for a more efficient use of energy from the compressor discharge, which can be utilized for heating, hot water, or other specific building services [2].

To assess the potential for energy recovery, it is crucial to develop a model of the facility that can align recovery opportunities with the corresponding service consumption. This necessitates a computational model that accurately replicates the behaviour of the actual installation. This study entails the creation of a grey-box model for a CO2 booster-type refrigeration system. This model integrates a theoretical framework of the installation with data from real facilities to better mirror real-world behaviour. The equations describing the thermodynamic model of the installation were implemented in the Scilab software [3], utilizing the thermodynamic properties from the CoolProp software library [4]. These equations are outlined in [5]; in this prior work, authors implemented the model to analyse different strategies for optimizing the heat recovered in the de-superheater. The model delineates how the system functions under ideal steady-state conditions, but it is necessary to adjust some operational parameters to accurately emulate the system's behaviour.

The available data from the installation's telemetry included evaporator pressure, gas cooler/condenser pressure, compressor input and output temperatures, gas cooler/condenser output temperature, and compressor capacity. Telemetry data was obtained from the database Verisae [6]. This data was provided at five-minute intervals. Unfortunately, mass flow rates were not supplied via telemetry, so it was necessary to obtain this data from the compressor manufacturer's web application Bitzer [7]. This application allows for the determination of mass flow rates for each line based on specific working parameters. The objective was to obtain results for four different operating points in each group of compressors and characterize them in terms of volumetric and overall performance. A linear equation dependent on the compression rate was adequate for volumetric performance, while a quadratic equation sufficed for overall performance. These adjustments enabled us to ascertain the volumetric flow rate moved by the low and high-pressure compressors under each condition.

A final critical consideration was the validation of the model. Different compressor capacities needed to be taken into account depending on the supermarket's schedule, as during closed hours, cabinets were shielded with curtains to conserve energy. Using the telemetry data, the dependency of compressor capacity on outdoor temperature and supermarket schedule was determined.

The final grey-box model developed depends only on outdoor temperature and the supermarket schedule. When comparing the results of electrical power consumption between the model and actual data for the period from 11th July 2017 to 11th July 2018, the average error in instantaneous power calculation was 11%. While this may seem high, it is important to note that the annual consumption error was only 0.12%. This demonstrates that the model provides a reasonable approximation given the limitations in input model variables.

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