Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Engineering Applications of Artificial Intelligence 19 (2006) 113–126
Engineering Applications of ARTIFICIAL INTELLIGENCE
www.elsevier.com/locate/engappai

Applications of artificial intelligence for optimization of compressor scheduling

Hanh H. Nguyen, Christine W. Chan*

Faculty of Engineering, University of Regina, Regina, Saskatchewan, Canada S4S 0A2

Received 2 April 2005; received in revised form 13 June 2005; accepted 16 June 2005
Available online 10 October 2005

Abstract

This paper presents a feasibility study of evolutionary scheduling for gas pipeline operations. The problem is complex because of several constraints that must be taken into consideration during the optimization process. The objective of gas pipeline operations is to transfer sufficient gas from gas stations to consumers so as to satisfy customer demand with minimum costs. The scheduling involves selection of a set of compressors to operate during a shift. The scheduling decision has to be made so as to satisfy the dual objectives of minimizing the sum of fuel cost, start-up cost, the cost of gas wasted due to oversupply, and satisfying minimal operative and inoperative time of the compressors. The problem was decomposed into the two subproblems of gas load forecast and selection of compressors. Neural networks were used for forecasting the load; and genetic algorithms were used to search for a near optimal combination of compressors. The study was conducted on a subsystem of the pipeline network located in south-eastern Saskatchewan, Canada. The results are compared with the solutions generated by an expert system and a fuzzy linear programming model.

Keywords: Genetic algorithms; Neural networks; Compressor scheduling

1. Introduction

Evolutionary scheduling for gas pipeline compressor is a complex problem because of constraints that must be taken into consideration during the optimization process. Such constraints include operation cost, maintenance cost, and customer satisfaction. This paper reports on a feasibility study on applying Artificial Intelligence technologies to natural gas pipeline operations. The focus of the study was on the St. Louis East gas pipeline distribution system, a subsystem of the pipeline network located in southeastern Saskatchewan. The system consists of two stations located at Melfort and St. Louis. The two stations use compressors to generate sufficient pressure to transport gas to the surrounding consumption areas of St. Brieux, Nipawin and Hudson Bay. The dispatchers' task is to adjust the compression level in order to generate the necessary pressure while not wasting energy. When the customer demand increases, a dispatcher adds compression to the pipeline system by turning on one or more compressors. On the other hand, the dispatcher turns off one or more compressors to reduce compression in the pipeline system when the customer demand decreases. This decision has a significant impact on effectiveness of the natural gas pipeline operation as well as on operating costs.

The objective of this study is to use automation techniques to aid the dispatcher in optimizing natural gas pipeline operations in order to satisfy customer demand with minimal operating costs. A dispatcher needs to know in advance when a large volume of gas is required and what way is the optimal to ensure it is

*Corresponding author. Tel.: +1 306 585 5225; fax: +1 306 585 4855.
E-mail addresses: nguyen4h@uregina.ca (H.H. Nguyen), Christine.Chan@uregina.ca (C.W. Chan).

0952-1976/$ - see front matter
doi:10.1016/j.engappai.2005.06.008

available. Previous studies were conducted in which expert system and linear programming (LP) technologies were employed to solve the problem. Here, we present a genetic algorithm (GA) system that generates workable schedules of compressor operation based on the current situation. Since the problem can be decomposed into two sub-problems of demand forecast and compressor selection, neural networks are employed to tackle the former problem of demand forecast and GAs are used for addressing the problem of compressor optimization.

This paper is organized as follows. Section 2 provides some background on the past solutions for the problem and the GA technique in general. Section 3 describes the first subtask, as well as development and results of demand prediction using neural networks. Section 4 discusses the second subtask, which involves analysis and implementation of GAs for optimization of compressor scheduling. Section 5 presents comparison of results generated by the three methods. Section 6 gives some conclusion and discusses some possible future work.

2. Background

2.1. Problem domain

This project was part of a study on automation of natural gas pipeline operations conducted jointly with a gas pipeline company in Saskatchewan, Canada. The objective of the study was on optimization of compressor scheduling and the study focused on a section of the Saskatchewan gas pipeline around the St. Louis East compressor station in the province of Saskatchewan, Canada. A schematic of the St. Louis East system is shown in Fig. 1.

The system consists of two compressor stations, Melfort and St. Louis. These compressor stations supply natural gas to two customer locations, Nipawin and Hudson Bay. In St. Louis, there are three compressor units; two of them are electrical compressor units and the other is a gas compressor unit. In Melfort, there are two gas compressors. An electrical compressor unit provides 250 hp and a gas unit provides 600 or 650 hp. The demand for natural gas from customers fluctuates depending on the season. In the winter, the demand for natural gas is usually higher than in the summer. In addition, the demand for natural gas also changes depending on the time of day. For example, in the morning, the demand is higher because the customer begins to use natural gas to warm the premise. In the afternoon, the demand is low since the facilities are already heated up in the morning. The customers can also be grouped into three types: industrial, dehydrator, and heat sensitive customers. Each type of customer reflects a different pattern of natural gas consumption as illustrated in Fig. 2.

The industrial customer has the same rate of natural gas consumption any time of the day. The dehydrator customer demands two set amounts of natural gas at different periods of time. For example, between 8:00 and 10:00 a.m., the demand is $240 \times 10^3\,m^3/day$ while between 10:00 am to 12:00 am, the demand is $200 \times 10^3\,m^3/day$. The demand of the heat sensitive customer fluctuates over time and is difficult to predict. In practice, the demand for natural gas can fluctuate from $200 \times 10^3\,m^3/day$ to over $560 \times 10^3\,m^3/day$ within 1 or 2 h. A demand of $200 \times 10^3\,m^3/day$ can be handled from St. Louis with one compressor unit. When the demand exceeds $560 \times 10^3\,m^3/day$, all units at St. Louis and both units at Melfort are needed. To ensure customer satisfaction, the operator needs to know beforehand and be ready for the largest volume requirement of gas. Otherwise, the system pressures at Nipawin and Hudson Bay will be below the required minimum.

The graphs showing supply and demand of gas in the pipelines are generated during operations by the simulator program of the gas pipeline transmission company. The display includes a compressor discharge pressure curve vs. customer station pressure curve as shown in Fig. 3. The two curves in Fig. 3 provide pressure information to dispatchers, and indicate the relationship between demand and supply. The gap between the two curves is called the comfort zone (CZ). If this CZ is wide, then customer satisfaction is

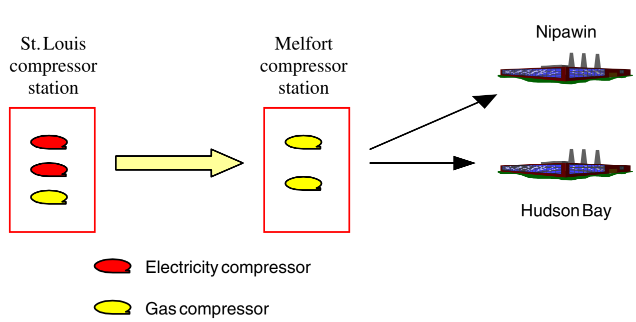

Fig. 1. Schematic of the St. Louis East system.

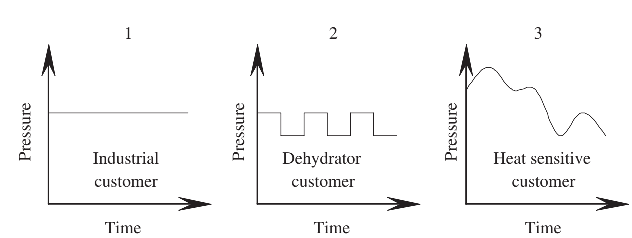

Fig. 2. Different natural gas consumption patterns.