UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF COST REDUCTION MATHEMATICAL MODEL FOR NATURAL GAS TRANSMISSION NETWORK SYSTEM

MEHRDAD NIKBAKHT ELIADERANY

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By

MEHRDAD NIKBAKHT ELIADERANY

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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DEVELOPMENT OF COST REDUCTION MATHEMATICAL MODEL FOR NATURAL GAS TRANSMISSION NETWORK SYSTEM

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Chairman: Norzima Zulkifli, PhD

Faculty: Engineering

Natural Gas Transmission Systems (NGTSs) have been designed to transmit a huge amount of Natural Gas (NG) at high pressure from the refineries to Natural Gas Distribution Systems (NGDSs) and some of consumers such as power plants and exportations. In these systems, NG is sent to sales point through pipelines, and Compressor Stations (CSs).

The main problem in the NGTSs was a lack of researches that minimize the total cost of the natural gas transmission network, which is included most transmission pipeline and compressor stations parameters simultaneously. The next problem was referred to solve NGTSs models. Because developed mathematical models for optimization NGTS problems have been known as a complex problem especially in the real-world cases.

In this research, the objective was to develop a new mathematical model to minimize the costs of the Natural Gas Transmission Supply Chain (NGTSC) system by considering various design factors such as diameter, thickness, pressure, temperature, length, and compressor ratio. To achieve this, other objectives were targeted such as, to design a multi-echelon supply chain for the NGTSCs, to develop Extended Genetic Algorithms (EGAs), for solving the model, and to validate the mathematical model with a real world case study in natural gas industry.

This research separated Natural Gas Gathering Systems (NGGSs), which was relating to the collected natural gas from the wells and transmit it to the refineries from the NGTSs. Therefore, a new classification proposed on the natural gas networks from the oil and gas wells to the consumers. In addition, a multi-echelon supply chain was designed for NGTSs named Natural Gas Transmission Network Supply Chain (NGTSC). It was used for integrating the operational parts of the natural gas industry for transmitting gas through pipelines and better coordination for the flow of gas and information in the system.

A new Mixed Integer Non-Linear Programming (MINLP) mathematical model was developed for the optimization of the NGTSC that named NGTSCM. The model formulated by using gas hydraulic equations such as Weymouth, compressor horsepower, Reynolds number and gas velocity equations. Some factors, such as the gas pipeline diameters and compressor power, had a greater impact on network costs,

and therefore, there was a need to reduce them. To achieve this, the problem was presented as a formula.

Since the optimization problem in NGTSs was non deterministic polynomial and this complexity would be increased for the development of the NGTSC in the proposed MINLP model, exact methods had to be replaced with metaheuristic methods for finding the global optimum solution. In this research, an Extended Genetic Algorithms (EGA) was investigated to solve the proposed mathematical model and to achieve global or near to global optimum solutions in a reasonable time.

To verify the model, a natural gas transmission example from literature was considered, and to present the model validity one real case study was studied. The results obtained from problem were analyzed based on the objective function, and the design parameters of the network. Analysis of results illustrated the priority of the NGTSCM compared to the other design methods. Through one to one comparison of the costs of the networks, it was clear that, the costs, as calculated using the optimal method, were reduced by 2.91 % in first case, and 0.94 % in second case in comparison with another method. By using this model, the compressors' power or ratios were decreased and the pressure and distance between compressors were increased. Thus, the total cost of the network was decreased. Therefore, the data clearly exhibit that the proposed method provides a solution that was nearer to an optimized network.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN MODEL MATEMATIK BAGI PENGURANGAN KOS PENGHANTARAN GAS ASLI UNTUK SISTEM RANGKAIAN PENYALURAN GAS ASLI

Oleh

MEHRDAD NIKBAKHT ELIADERANY

Mei 2012

Pengerusi: Norzima Zulkifli, PhD

Fakulti: Kejuruteraan

Sistem Penyaluran Gas Asli (NGTSs) telah direka untuk menghantar jumlah yang besar Gas Asli (NG) pada tekanan tinggi daripada kilang penapisan untuk Sistem Pengagihan Gas Asli (NGDSs) dan beberapa pengguna seperti loji janakuasa dan exportations. Dalam sistem ini, NG dihantar ke titik jualan melalui saluran paip, Stesen Pemampat (CSS) dan lain-lain peralatan yang mahal.

Masalah utama dalam NGTSs adalah kekurangan penyelidikan yang meminimumkan jumlah kos rangkaian penghantaran gas asli, yang termasuk saluran paip yang paling penghantaran dan stesen pemampat parameter serentak. Masalah seterusnya dirujuk menyelesaikan model NGTSs. Kerana membentuk model matematik untuk pengoptimuman masalah NGTS telah dikenali sebagai satu masalah yang rumit terutama dalam kes-kes dunia sebenar.

Dalam kajian ini, objektif ialah untuk membangunkan model baru matematik bagi mengurangkan kos Penghantaran Percuma Rantaian Bekalan Gas Asli (NGTSC) dengan mengambil kira faktor reka bentuk yang pelbagai seperti diameter, ketebalan, tekanan, suhu, panjang, dan nisbah pemampat. Untuk mencapai matlamat ini, objektif lain disasarkan seperti, untuk mereka bentuk rantaian bekalan pelbagai eselon untuk NGTSCs, untuk membangunkan algoritma genetik (EGAs), untuk menyelesaikan NGTSCM, dan untuk mengesahkan model matematik dengan dunia sebenar kajian kes di semulajadi industri gas.

Kajian ini memisahkan Sistem Gathering Gas Asli (NGGSs), yang berkaitan gas asli yang dikutip dari telaga dan penghantaran ke kilang penapisan dari NGTSs. Oleh itu, baru mengklasifikasikan mencadangkan pada rangkaian gas asli dari telaga-telaga minyak dan gas kepada pengguna. Di samping itu, pelbagai eselon rantaian bekalan direka bagi NGTSs yang bernama Gas Asli Penghantaran Rangkaian Rantaian Bekalan (NGTSC). Ia digunakan untuk mengintegrasikan bahagian operasi industri gas asli untuk mengangkut gas melalui talian paip dan penyelarasan yang lebih baik untuk aliran gas dan maklumat dalam sistem.

Satu baru Campuran Integer Bukan Linear Programming (MINLP) model matematik dibangunkan untuk pengoptimuman NGTSC yang dinamakan NGTSCM. Model merumuskan dengan menggunakan persamaan gas hidraulik seperti Weymouth, kuasa kuda pemampat, nombor Reynolds dan persamaan halaju gas. Beberapa faktor, seperti diameter saluran paip gas dan kuasa pemampat, mempunyai impak yang lebih

besar pada kos rangkaian, dan oleh itu, terdapat keperluan untuk mengurangkan mereka. Untuk mencapai matlamat ini, masalah itu dibentangkan sebagai satu formula.

Sejak masalah pengoptimuman di NGTSs adalah NP-keras dan kerumitan ini akan meningkat untuk pembangunan NGTSC dalam model MINLP yang dicadangkan, kaedah yang tepat untuk digantikan dengan kaedah metaheuristic untuk mencari penyelesaian optimum global. Dalam kajian ini, Algoritma Genetik Extended (EGA) disiasat untuk menyelesaikan model matematik yang dicadangkan dan untuk mencapai global atau dekat dengan penyelesaian global yang optimum dalam masa yang munasabah.

Untuk mengesahkan model, satu contoh dipertimbangkan, dan untuk kesahihan model satu kajian kes sebenar dikaji. Keputusan yang diperolehi daripada masalah di analisa berdasarkan fungsi objektif, dan parameter reka bentuk rangkaian. Analisis keputusan menggambarkan keutamaan NGTSCM itu berbanding dengan kaedah reka bentuk yang lain. Melalui perbandingan kos rangkaian, ia adalah jelas bahawa kos, seperti yang dikira menggunakan kaedah optimum, berkurangan sebanyak 2.91% dalam kes pertama, dan 0.94% dalam kes kedua perbandingan dengan kaedah lain. Dengan menggunakan model ini, kuasa atau nisbah pemampat menurun dan tekanan dan jarak antara pemampat meningkat. Oleh itu, jumlah kos rangkaian telah menurun. Oleh itu, data yang jelas menunjukkan bahawa kaedah yang dicadangkan menyediakan penyelesaian yang lebih dekat kepada rangkaian yang dioptimumkan.

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DEDICATION

With love and gratitude to my wife, Marzieh and my daughters, Negin and Shamim

I certify that a Thesis Examination Committee has met on 29 May 2012 to conduct the final examination of Mehrdad Nikbakht Eliaderany on his thesis entitled " Development Of Cost Reduction Mathematical Model For Natural Gas Transmission Network System " in accordance with the Universities and University College Act 1971 and the Constitution of University Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Tang Sai Hong, PhD
Associate Professor
Faculty of Engineering
University Putra Malaysia
(Chairman)

Faieza, Abdul Aziz, PhD
Senior Lecturer
Faculty of Engineering
University Putra Malaysia
(Internal Examiner)

Mohd Khairol Anuar, Mohd Ariffin, PhD
Associate Professor
Faculty of Engineering
University Putra Malaysia
(Internal Examiner)

Kongkiti Phusavat, PhD
Associate Professor
Kasetsart University
Thailand
(External Examiner)

_____

SEOW HENG FONG, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 27 August 2012

This thesis was submitted to the Senate of University Putra Malaysia and has been accepted as fulfillment of the requirement for the Degree of Doctor of Philosophy. The members of Supervisory Committee were as follows:

Norzima, Zulkifli, PhD
Senior Lecturer
Faculty of Engineering
University Putra Malaysia
(Chairman)

Napsiah, Ismail, PhD
Professor
Faculty of Engineering
University Putra Malaysia
(Member)

Shamsuddin, Sulaiman, PhD
Professor
Faculty of Engineering
University Putra Malaysia
(Member)

Mohammad, Suleiman, PhD
Professor
Faculty of Mathematics
University Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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MEHRDAD NIKBAKHT ELIADERANY

Date: 29 May 2012

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