OPTIMUM PLANNING OF AIR COMPRESSORS NETWORK UNDER DIFFERENT ELECTRICITY TARIFFS

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in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled “Optimum Planning of Air Compressors Network Under Different Electricity Tariffs" is the result of my work except as cited in the references

Signature :...

Name :...

Date :...

APPROVAL

I hereby declare that I have read this project report and in my opinion, this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature :...

Supervisor's Name :...

Date :...

DEDICATION

To my beloved mother and father

ABSTRACT

A compressor is equipment which supplies compressed air to the production lines as production is always a very important prospect for any kind of industry. The compressed air is used as the main power source in various kinds of applications. Some examples of the applications are vacuum packaging, tire inflation, heavy lifting or loading and many more depend on the operation of the industries. This compressor also equipment that consumes huge power and energy as well as the electricity cost. Therefore, the industry needs to have efficient planning to control its power supply, input, and output during the operation. Regarding that, optimum planning of the air compressors network is important as initial preparation for the industry before starting operating.

ABSTRAK

Pemampat adalah peralatan yang membekalkan udara termampat ke lini pengeluaran kerana pengeluaran selalu merupakan prospek yang sangat penting bagi industri jenis apa pun. Udara termampat digunakan sebagai sumber kuasa utama dalam berbagai jenis aplikasi. Beberapa contoh aplikasi adalah pembungkusan vakum, inflasi tayar, pengangkatan atau pemuatan berat dan banyak lagi bergantung pada operasi industri. Pemampat ini juga peralatan yang menggunakan tenaga dan tenaga yang besar serta kos elektrik. Oleh itu, industri perlu mempunyai perancangan yang cekap untuk mengawal bekalan kuasa, input, dan outputnya semasa operasi. Sehubungan itu, perancangan optimum rangkaian pemampat udara adalah penting sebagai persiapan awal untuk industri ini sebelum mula beroperasi.

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I am extremely grateful to my parents for their prayers, love, caring, and sacrifices for educating and preparing me for the future. I also expressed my thanks to my beloved friends that involved with this project. Lastly, thank everyone that always supports me to accomplish this project.

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LIST OF ABBREVIATION

DSM	Demand Side Management
EE	Energy Efficiency
DR	Demand Response
MILP	Mixed Integer Linear Program
GAMS	General Algebraic Modelling System
TNB	Tenaga Nasional Berhad
TOU	Time of Use
ETOU	Enhanced Time of Use
AIMMS	Advanced Interactive Multidimensional Modeling System

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

A compressor is one of the most important mechanisms or equipment that most of the industry used to fulfill the production demand. The compressor unit will have compressed air before the supply air to the production units. The most common types of air compressors are rotary screw compressor, reciprocating air compressor, axial compressor, and centrifugal compressor. In the industry, the connection of the compressors is in the series or parallel based on the purpose of the system. These networks ofcompress can involve several compressor units that may differ in the type of drive and technical specifications (e.g., maximum load capacity, efficiency, and operational range)(Kopanos et al. 2015). The compressor network can be regulated under operational planning, energy scheduling, demand site management, electricity tariff, and resource management.

Every industry needs good operational planning for their compressors where it can achieve minimum power consumption and at the same time meets the demand for the production. The works related to the operational management of air separation systems are limited. Ierapetritou et al.(2002) presented a linear Mixed Integer Programming (MIP) formulation for the operational planning in an air separation plant under the objective to minimize the total operating cost. The operation ofthe plant was described by three different plant operation modes (regular, assisted, shutdown) that vary concerning operational efficiency and energy requirements. Binary variables were used to represent operating modes and switches among the different modes of operation. The model of (Ierapetritou et al. 2002) can generate the schedule of process operation modes and production rates. Along the same lines, (Karwan and Keblis 2007) proposed a MIP model that additionally considers product losses during configuration changes, while (Mitra et al. 2012) presented a MIP formulation that captures the transient behavior between different operating modes.

Moreover, multiple compressors in parallel connection are used to increase the total available capacity. The more compressors used the more power consumption need to run the compressors. The initiatives to reduce energy consumption or encourage consumers to achieve optimization are referred to as Demand Side Management (DSM). The most industrial goal is to perform and gain maximum profit with low energy consumption. However, what makes the DSM of industrial consumers challenging is rather the complexity of their underlying processes which demands a deep domain knowledge (Ramin, Spinelli, & Brusaferri, 2018). According to the TNB (Tenaga Nasional Berhad) official website stated that the Time of Use (TOU) scheme offers different times of the day. During the off-peak period, for example, tariff rates will be lower than the peak period. Figure 1.1.1 shows TNB's TOU time zone.

TOU Time Zones	
Time Zone	Hours
Peak	08:00 – 22:00 hours
Off-peak	22:00 – 08:00 hours

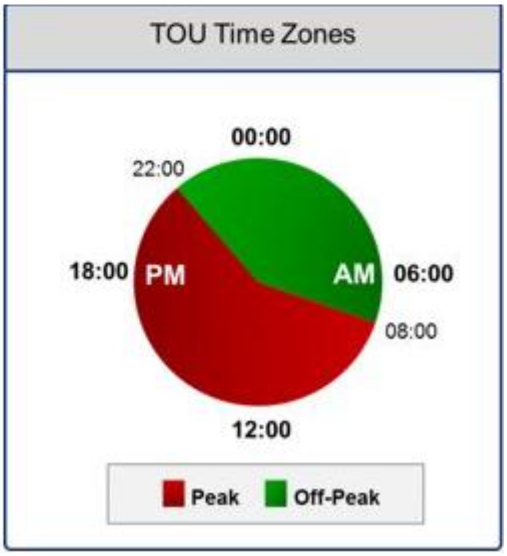

Figure 1.1.1 Time of Use (TOU) from TNB

1.2 PROBLEM STATEMENT

Industries world deals with a huge amount of energy consumption which comes from energy-intensive mechanical equipment for example compressor.The energy consumption will increase due to the high production demand.Regarding this issue, most industries will invest more costs to meet the production requirement. Besides, engineers nowadays use a spreadsheet to manage the plant. This traditional planning only can be handled by experienced engineers. It also not very systematic for the operational.

Moreover, mostindustriesdid not implement a modern planning system that will reach the maximum operational efficiency and minimize the cost of operation. In this study, mainly focus to achieve the optimization of the operation of the compressors by developing optimum planning of air compressors network under different electricity tariffs.

1.3 OBJECTIVE

The objectives of this project are as follows:

1. To investigate the current relation of energy consumption on the operational condition of the air compressors network
2. To formulate an optimization model that integrates with the planning of energy-intensive compressors network with different electricity tariffs
3. To demonstrate the capability of the proposed optimization model in terms of energy and cost minimization for optimum planning of industrial air compressors network

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. Consists of eleven compressors connected in parallel that supply compressed air to three processing units through three headers.
2. Parameter variables:
    i) Constraints related to start-up and shutdown actions.
    ii) Constraints related to the operational status and production level of the processing units.
    iii) Demands for final products.
    iv) Constraints related to the assignment of utility units to connecting lines.
3. The result for optimum planning is performed by using GAMS's software.
4. The demand for optimum planning is regulated electricity tariff for the E3 category.

Table 1.4.2: Industrial tariff for E3 categories

TARIFF E3 – HIGH VOLTAGE PEAK/OFF-PEAK INDUSTRIAL TARIFF	
For each kilowatt of maximum demand per month during the peak period	35.50 RM/kW
For all kWh during the peak period	33.70 sen/kWh
For all kWh during the off-peak period	20.20 sen/kWh
The minimum monthly charge is RM600.00	

CHAPTER 2

LITERATURE REVIEW

2.1 Compressor Network in Industry

A compressor is a primary function in the operation of natural gas pipelines. In the process industries, compressed air is needed to move their production system. The main duty for a compressor is to supply compressed air through pipelines either the connection is in series or parallel. Multiple compressors that connect in parallel will increase the total capacity for the industry. However, the more compressor operated at the same time will generate huge power consumption which means the cost will be increasing as well. Therefore, the ideal optimization of the compressor network should be implemented in the industry. As a result, power consumption costswill be minimized but still meets the demands required from the production units.

An optimal decision usage of the compressor will significantly impact the operating cost. The topic of utility system optimization has been studied well. As an example, Kopanos et al., (2015) and Xenos et. al,(2016) proposed an optimization model to improve the performance of the compressors. The model consists of the start-up and shutdown cost, operating status, and the power consumption of the compressor.Nguyen et. al,(2008)conduct a study on a comparison of three alternative approaches of mixed-integer linear programming(MILP), genetic algorithms (GA), and expert systems (ES) for optimization of compressor selection in a natural gas pipeline system. According to their research mixed-integer, linear programming (MILP) is mathematical programming unique in which the objective function and problem constraints are linearly defined and as a result, MILP solves problems using a simple linear branch-and-bound algorithm to minimize the overall operating cost. For the genetic algorithm (GA), it works well in time-constrained problems because theoptimal solution improves in every generation instead of being the result of a lengthy solution process. Next,the expert system approach uses primarily captured human heuristics for providing the basis for building automation solutions.

2.2 Operational Planning

Operational planning describes the plan made to meets the demands while scheduling can provide a clear view of the system. Planning and scheduling both need to accomplish the system efficiently. The main purpose of this operational planning is to achieved optimization in the production system. Operational planning takes several months and has an objective in determining production profile. A mathematical programming model that considers the operating constraints for compressors and performance degradation for compressors is implemented in this study. The planning consists of the operating status, the power consumption, the start-up and the shutdown costs for compressors, the compressor connectsto the header, the timing and the type of necessary maintenance tasks as well as the outlet mass flow rates for compressed air. Operational planning can be conducted either in a single production site or multisite production. Verderame & Floudas, (2009) maderesearch on the operational planning framework for multisite production and distribution networks and stated that multisite production produces efficient production utilization compared to a single production site.

Scheduling in an industry environment is very important to give a clear view process undergo for the plants or industries. In this study, scheduling focussed on the compressor network. Some industries used the traditional method for their scheduling which data collected from a spreadsheet while not many industries used modern scheduling which more systematic. By using scheduling, important data will be collected especially the operating cost. The optimum scheduling can be minimizing the supply air from the compressors to the production line and at the same time, the operating cost also will be minimized. Effective scheduling also will improve the productivity, resource utilization, and profitability of the plant or industry. The topic of scheduling is well studied and implemented in many kinds of equipment and for an example (Li, Huang, Zhao, & Liu, 2017) made a research about operation scheduling of multi-hydraulic press system for energy consumption reduction and developed scheduling formulation for grouped hydraulic presses as shown in Figure 2.2.1

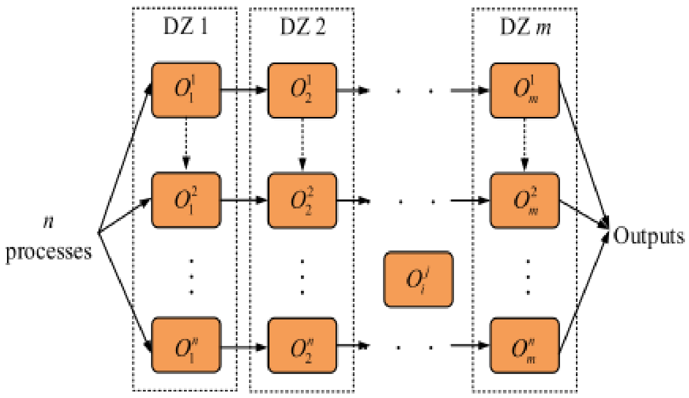

Figure 2.2.1: Operation procedures of each process in the grouped system

The other example of scheduling is from (Xenos et al., 2016)which provides an optimal schedule for the compressor to give the best decisions for their washing process.