OPTIMUM SCHEDULING OF ENERGY- INTENSIVE COMPRESSORS NETWORK UNDER REGULATED ELECTRICITY TARIFF

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DECLARATION

I declare that this project report entitled *"*Optimum Scheduling of Energy – Intensive Compressor Network under Regulated Electricity Tariff*"* is the result of my own work except as cited in the references

Signature : .....

Name : MUHAMMAD BAZLEY BIN SA'AT

Date : 24 JULY 2020

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 of the award of the degree of Bachelor of Mechanical Engineering

Signature :  .....

Supervisor Name : DR. NUR IZYAN BINTI ZULKAFLI

Date : 24 JULY 2020

DEDICATION

This study is dedicated to my father, who taught me that the best kind of knowledge to have which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

ABSTRACT

Compressed air is a major source of power transfer which has been used in various kind of application in industries. The example of application that widely used are heavy lifting and transports, tire inflation, dust removal, vacuum packaging, cutting, and slicing and many more. Compression air is a major source of energy transfer. Industries have been professional in their initial designs to incorporate details on their systems so that the air compressors can automatically analyse on operating status and output parameters to the compressor operators. Most of heavy industries used compressors network where it can work at higher pressure points than commercial industries. Therefore, it going to use at high pressure at certain time. Regarding to that, the application of incentive-based strategy is going to apply to minimize the runtime of compressor. The objective of this case study where to investigate the current relation between the operational and energy scheduling of energy intensive. Then, formulate an optimization model for scheduling of energy-intensive compressors network under regulated electricity tariff. From that, the energy and cost benefits of the proposed optimization model will be defined. By using General Algebraic Modeling System (GAMS) software the operational of air compressor can be optimizing which the data from the research such as start-up and shutdown compressor, minimum and maximum runtime, and change of connection line to maximize the demand and inventory level for every compressor unit is input into GAMS software. The software will generate all the equation and come out with the minimum total power cost after 21 days operation.

ABSTRAK

Udara mampatan adalah sumber utama pemindahan tenaga yang telah digunakan dalam berbagai jenis aplikasi di industri. Contoh aplikasi yang digunakan secara meluas ialah pengangkatan dan pengangkutan berat, inflasi tayar, penyingkiran habuk, pembungkusan vakum, pemotongan, dan pemotongan dan banyak lagi. Udara mampatan adalah sumber utama pemindahan tenaga. Industri telah profesional dalam reka bentuk awal mereka untuk memasukkan perincian pada sistem mereka sehingga pemampat udara secara automatik dapat menganalisis status operasi dan parameter output kepada operator pemampat. Sebilangan besar industri berat menggunakan rangkaian pemampat di mana ia dapat berfungsi pada titik tekanan yang lebih tinggi daripada industri komersil. Oleh itu, ia akan digunakan pada tekanan tinggi pada waktu tertentu. Sehubungan dengan itu, penerapan strategi berbasis insentif akan diterapkan untuk meminimumkan waktu pemampatan pemampat. Objektif kajian kes ini adalah untuk mengkaji hubungan semasa antara penjadualan operasi dan tenaga dengan intensif tenaga. Kemudian, rumuskan model pengoptimuman untuk penjadualan rangkaian pemampat intensif tenaga di bawah tarif elektrik yang diatur. Dari itu, manfaat tenaga dan kos model pengoptimuman yang dicadangkan akan ditentukan. Dengan menggunakan perisian General Algebraic Modeling System (GAMS), operasi pemampat udara dapat mengoptimumkan data dari penyelidikan seperti pemampat pemula dan pemutus, runtime minimum dan maksimum, perubahan saluran sambungan untuk memaksimumkan permintaan dan tingkat persediaan untuk setiap unit pemampat dimasukkan ke dalam perisian GAMS. Perisian ini akan menghasilkan semua persamaan dan mengeluarkan dengan jumlah kos kuasa minimum setelah 21 hari beroperasi..

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LIST OF ABBREVIATION

TOU	Time of Use
ETOU	Enhance Time of Use
TNB	Tenaga Nasional Berhad
GAMS	General Algebraic Modeling System
MILP	Mixed-Integer Linear Programming

LIST OF SYMBOLS

t	Duration of each time
ω_i	Minimum runtime for compressors
$\widetilde{\omega_\iota}$	Total number at beginning of planning horizon for compressor
$X_{(i,t)}$	Compressor network operating during time period t
$S_{(i,t)}$	Start up at the beginning of t
$F_{(i,t)}$	Shut down in initial time t
$\tilde{X}_i$	Initial operating status
φ_i	Minimum shutdown time for compressor
$\tilde{Q}_{(i,t)}$	Operating production level of compressor
$K_{(i,t)}^{UT,min}$	Production level of compressor
$B_{(e,z,t)}^{UT,+}$	Flow of compressor network in storage tank for period t
$Z_{e,}$	Inventory can store compress air in tank
λ_n^{max}	Maximum number of products

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CHAPTER 1

INTRODUCTION

1.1 Background

Network compressor is commonly used in industrial sector for machinery. Compressor unit supply compress air to header where every single header link with storage tank and supply to the processing unit. To achieve the fourth industrial revolution, the concept describes manufacturing facilities for all machines including the air compressors with their corresponding sensor. In global market, most of the company applying for environmental regulation to ensure the energy will be maximized to save the cost. In demand side management it has several merits which is reducing the cost, and this is great for industries. (Basu, 2020) Generally, for industrial equipment most of the machine are interrelated from the initial to the final production system. The efficiency of compressor network is important to ensure the entire system which air storages, air dryer, receiver, and after-cooler in a good condition. For the operation system, the compressor network in industry need to maintain the efficiency of compressor by using optimization method. It will be easier for optimum scheduling of energy intensive. To present the better computationally methods for minimizing the cost of compression under dynamic condition where the industry should describe by time-dependent mass flow. Moreover, the operation process for network compressor through converting inexpensive electricity power must be justify achieving the optimal rate to reduce cost. Most of the utility system in industrial have make a system by directly linked with pipeline to ensure the high profit in production line based on the demand (Zulkafli & Kopanos, 2016). Moreover, the facilities in industries using compress air system as the main energy and it shows that how the network compressor influences in electrical

energy such factor include type, model, size, motor power rating, system design and control mechanisms. The main reason where the causes of inefficient network compressor is when the heat loss which generated from the increased temperature in air and caused by friction from the part moving. Other than that, compress air system is consuming high amount of energy and there are huge losses due to pressure and air flow rate drop (Taheri & Gadow, 2017). If the right method applies for the network compressor system, it will be going to save cost and energy.

1.2 Problem Statement

To reduce cost for electricity, the optimum strategy must be planned to maintain the production line at maximum peak value. Regarding to the charged from electricity tariff, the optimum scheduling tools for each equipment in industry must be applied to make sure that all equipment uses in range of saving energy. In industrial sector the electricity price is depends on power consumption uses and it is much related with demand side management to control the power users for every equipment. Based on data in annual energy outlook 2019, the energy consumption increases 0.9% per year from 2018(*Annual Energy Outlook 2019*, 2019). From the increasing of energy consumption, the total demand for all fuel also increased. Therefore, this case study will be done by formulating the optimization model with ideal strategy for energy-intensive in compressor network. Besides, from this case study the current trend for the demand side management will be generated to make sure that the operation of energy-intensive in each mechanical equipment in industry will be calculated of energy-intensive in each mechanical equipment in industry will be calculated.

1.3 Objective of Study

(a) To investigate the current relation between the operational and energy scheduling of energy-intensive mechanical equipment.

(b) To formulate an optimization model for scheduling of energy-intensive compressors network under regulated electricity tariff.

(c) To evaluate the energy and cost benefits of the proposed optimization model through the use of comprehensive analysis.

1.4 Scope of Study

Based on the study it will be focusing on the development scheduling energy-intensive for compressor network. To achieve efficient energy use, sometimes it can be simplified energy efficient to reduce the amount of energy required to provide the losses from the machine equipment. From the case study it consists of 11 compressor which is (i1, i2, i3, i4, i5) for small compressor and (i6, i7, i8, i9, i10, i11) for big compressor. Each compressor supplies the compress air for every processing unit through storage tank and header. Every processing unit must consist of only one storage and one header. To achieve the optimum runtime, the time of uses (TOU) is important to make sure that compressor run in a certain peak or off-peak time. For example, by running the network compressor at certain time can provide from higher charge from electricity tariff. In certain cases, penalty cost will be charged if the final product from external sources and for the changes of utility unit. By using GAMS software, it will be easier to formulate the mathematical model to finding optimal solution to optimization problems.

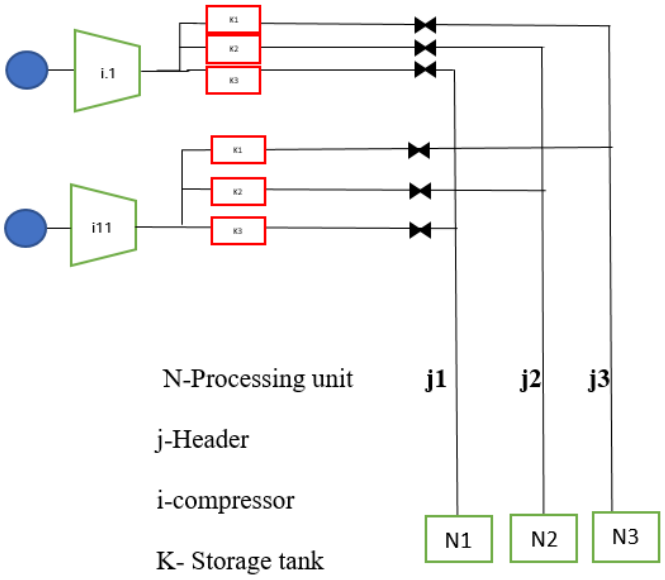

Figure 1.1 Layout of the Network Compressor

Table 1.1 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	

Table 1.2 Time Zone Classified

ETOU time zone		
Time zone	Industrial E3 HV ETOU	Hour
	Energy Charge (cent/kWh)	
Mid-peak	32.70	08:00-11:00 Hours
Peak	57.60	11:00-12:00 Hours
Mid-peak	32.70	12:00-14:00 Hours
Peak	57.60	14:00-17:00 Hours
Mid-peak	32.70	17:00-22:00 Hours
Off-peak	20.20	22:00-08:00 Hours

1.5 Expected Finding

From Table 1.3 below, the main problem is to calculate the maximum of the total profit. It consists of five type of chemical and each chemical through the two-chemical process. After the chemical through the process, it will be going to the final process which is packaging for each chemical. Regarding to the process three equipment will be used for process one and two equipment for process two. Each unit required a certain time in hour on each process as given table below.

Table 1.3 Chemical with Process

	Chemical 1 $550	Chemical 2 $600	Chemical 3 $350	Chemical 4 $400	Chemical 5 $200
Process 1	12	20	-	25	15
Process 2	10	8	16	-	-

Solution:

By using GAMS method, it will be easier to formulate a mathematical model for optimal solution to optimization problem as shown in table below the total highest profit come out.

Table 1.4 Higher Chemical and Process

	Chemical 1	Chemical 2
Process 1	24000	-
Process 2	-	24000
Packing	-	19200
Total profit: 39120.000		

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this develop world, most of the equipment in industries use network compressor or air compressor as the main energy supply to move each part in every equipment. To make sure all equipment receive enough compress air to the machine, the system has been controlling with master controller and the ability of the unit can collect and communicate data. Regarding to the major uses of network compressor in industry, it is quick good to apply incentive based strategy for optimum scheduling of energy-intensive for compressor network to ensure that the daily use of power consumption for network compressor will be minimize. The operational for network compressor commonly depends on the uses of every equipment in certain time. By using optimum scheduling, the compressor network supply will be minimizing their operating cost where much more related with regulated electricity tariffs. In fact, most of the electricity today are mostly based on the fossil fuel power plant (Benato & Stoppato, 2019) and from that statement shows that, it is important to minimize the uses of electricity for future generation.

2.2 Demand side management

It becomes important to inspect on the optimum scheduling of power generation due to the increases of renewable energy needed. The extremely problem issue about nature in renewable energy resources and the higher loss will cause a bad effect on the industries sector. Based on the research showed that a good recommends to solve this issue by

implementing all system in industries with demand side management. From that all problem regarding to the power consumption will be reduced (Basu, 2020). The recent issue makes the energy generation technologies mostly consist of renewable which have been triggered significant on the development for future sustainable solution.

Moreover, to gain the best development basically need more efficient consumption and the suitable keys related with that is demand side management (DSM) where the consumer can change their own profile for energy consumption. From this context, department in energy management system come into view at some of the implementation from operator system and mostly focus on the major application in energy uses at certain equipment. This platform will be calculating that optimization of energy consumption use according to preference on monitoring the data provided and how efficient use of energy (Gomes et al., 2019). According to the international energy agency's tactical plan, the demand side management is championed as the prime option of the entire energy policy verdicts. In demand side management system have several benefits such as reducing cost, increasing the reliability of the power system. In this department, it is more related to the time of use (TOU) program where some percentage of load demand to be fixed.

The demand side management are effective to be apply in industries because it effectively relief the problem on how to manage the uses of power consumption. It could be observed by make sure the peak of power load does not change, where's the maximum load has been transferred into the system such as the charging peak has moved from 19:00-18:00 to 16:00-18:00 (Wang et al., 2019). It shows that, the total unit in line order meet the power demand at peak period. The power output of expensive unit will easily reduce from the good demand shifting regarding to the proper algorithms. By using the optimal demand side management, it also can influence of peak shifting in certain value.

To reach sustainable development targets, growing body of literature on able demand side management theories, framework, policies and application in various sector all around the world. It helps from distinct actor by various ways such as lowering the bill payment for end-user, developing a strength point for the certain resources (Wang et al., 2019). Applying the optimal management, it will affect extra building can be connected to the network without installing new pipeline and good renewable energy sources can be reached (Wang et al., 2019).

2.3 Regulated tariffs

According to the Energy Information Agency (EIA) Tariff is the formation to determine the updated pricing for supplier charges to customer for energy consumption. An electricity tariff is the price unit at which electricity is sold and will be measured in rate per kilowatt-hour (kWh) of power consumed. For one kilowatt-hour (kWh) it refers to the amount of electricity consumed when the appliance of one kilowatt power rating runs in sixty minutes. Besides, electricity tariff is known as one unit of electricity where every appliance has different value of power ratings and differently power consumption calculated.