ENERGY EFFICIENCY IN WATER PUMPING SYSTEM

CHIN KWANG YHEE

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "Investigation On Structural Vibration Problem At MARS Building UTeM" is the result of my own 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 (Structure & Materials).

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

To my beloved mother and father

ABSTRACT

As the natural resources are consumable, energy efficiency is gaining attentions from various parties as excessive consumption of energy means lower in profit and more impact on the environment. Among all, buildings, especially university buildings had recorded among the highest energy consumption buildings. On the other hand, among all the components exist inside a building, the pumps which function to provide water supply to high rise gain less attention in energy efficiency evaluation. However, pumps are among the highest energy consumption component of electric motor applications. Hence, this research is conducted to investigate the current water pumping system in the Green Building, UTeM for energy saving opportunities. In order to do so, the optimization rating of the current water pumping system is estimated using Pumping System Assessment Tool (PSAT). Field data such as flow rate, head, motor power and voltage were first collected from the nameplates, catalogue or field measurements and filled into the Field Data Collection Form. The field data, motor power consumption is then being validated by determining the average motor power consumption recorded manually within an hour and on the other hand investigating the correlation between power consumption and number of people in the building. With the average motor power consumption be within the range of the data recorded previously and the positive correlation exists in between the two variables, the research is then proceeded with the simulation of optimization rating using the data of validated power consumptions. By using the maximum power consumption recorded, the optimization rating of the pump is recorded to be 142.0%, with the motor efficiency recorded to be 89%, which is even higher than the efficiency specified on the nameplate, indicating that the efficiency of the current system is optimized. However, the optimization rating is decreasing with the increasing value of motor power. Such phenomenon obeys the equation for efficiency.

ABSTRAK

Sumber semula jadi adalah terhad tetapi penggunaan tenaga pula semakin diperlukan. Oleh itu, kecekapan tenaga semakin dititik-beratkan sedangkan penggunaan tenaga secara berlebihan mengakibatkan kurang keuntungan dan membawa impak terhadap alam sekitar. Bangunan, terutamanya bangunan universiti merupakan antara penguna tenaga yang dicatat dengan penggunaan tenaga yang paling tinggi. Antara semua komponen yang terkandung dalam sebuah bangunan, pam yang berfungsi untuk menyediakan bekalan air kepada bangunan tinggi mendapat perhatian yang rendah dalam penilaian kecekapan tenaga. Walau bagaimanapun, pam merupakan antara komponen yang mencatat penggunaan tenaga yang paling tinggi antara aplikasi motor electrik. Oleh sebab itu, kajian ini dijalankan untuk mengkaji sistem pam air dalam Bangunan Hijau, UTeM untuk peluang penjimatan tenaga. Dalam usaha untuk membuat demikian, nilai pengoptimuman sistem pam air untuk Bangunan Hijau dianggar dengan menggunakan Pumping System Assessment Tool (PSAT). Data semasa seperti kadar aliran, kepala, kuasa motor dan voltan dikutip dengan merujuk kepada pelat nama, katalog dan pengukuran dalam bilik pam. Semua data yang dikutip diisi ke dalam borang yang disediakan. Antara data semasa yang didapat, data kuasa motor disahkan dengan menentukan purata penggunaan kuasa motor yang dicatatkan secara manual dalam masa sejam. Selain itu, data kuasa motor juga disahkan dengan menyiasat korelasi antara penggunaan kuasa dan bilangan orang dalam bangunan. Kuasa motor dapat disahkan purata penggunaan kuasa motor dicatat dalam kalangan data penggunaan kuasa motor yang dicatat sebelum itu dan korelasi positif wujud antara kedua-dua pemboleh ubah. Penyelidikan diteruskan dengan simulasi nilai pengoptimuman menggunakan data yang teleh disahkan. Dengan menggunakan penggunaan kuasa maksimum yang dicatat, nilai pengoptimuman didapati sebagai 142%, dengan kecekapan motor yang setinggi 89%, lebih tinggi daripada kecekapan motor yang dinyata di atas pelat nama. Ini menunjukkan bahawa system pam air Bangunan Hijau beroperasi dalam keadaan yang terbaik. Walau bagaimanapun, nilai pengoptimuman semakin kurang apabila nilai penggunaan kuasa motor meningkat. Fenomena ini mematuhi persamaan untuk kecekapan.

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LIST OF ABBEREVATIONS

PSAT	Pumping System Assessment Tool
DOE	Department of Energy
OIT	Office of Industrial Technologis
EU	European Union
CRP	Cold Rolling Process
CGP	Continuous Galvanizing Process
CCL	Colour Coating Process
TPM	Temper Mill
ASD	Adjustable Speed Drive

LIST OF SYMBOL

P_s	=	Shaft power
m	=	Mass flow rate
g	=	Gravitational acceleration
ΔH	=	Total dynamic head
Δu	=	Changes in internal energy
p	=	Pressure
ρ	=	Density
V	=	Velocity
Z_e	=	Elevation head
Δh_f	=	Pressure drop due to friction
f	=	Darcy friction factor
L	=	Pipe length
D	=	Pipe diameter
Q	=	Pump flow
n	=	Pump speed
h	=	Pump head
P_p	=	Pump brake horsepower
η_e	=	Motor efficiency
η_{ws}	=	Wire-to-shaft efficiency of the motor and variable-speed drive
η_p	=	Pump efficiency

P_c = Input power

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, energy efficiency is gaining concerns from a growing number of parties worldwide due to limited natural resources and the rapid growth of fossil fuels consumption. Organizations of industrial sectors would be concentrate in the efforts of improving the energy efficiency of the utilities they own, as excessive consumption of energy eat up the profits of the company, the same may goes to commercial and academic buildings.

According to Saidur (2010), among all the 14 countries selected, including Malaysia, an average of about 55.36% of the total energy generated was account for the operation of motor driven systems. As one of the component of a motor driven system, pumps possess a great deal of potential to contribute in energy saving. Hence, pump system optimization is introduced and gaining attentions from the energy auditors of various organizations.

As one of the efforts in improving energy efficiency, based on Rosen and Kandiah (2015), pump system optimization is a systematic approach to evaluate high energy use pumps to look for energy saving opportunities. For the purpose of the evaluation mentioned, pre-screening is first needs to be carried out to identify the pumps that are with greater saving opportunities. After the pre-screening process, the potential savings are determined by collecting data such as pressure, flow and power in the field. These data, upon combined with the pump system operational data, the energy use baseline and the true system requirements can therefore be identified.

For the usage of the United States Department of Energy's (DOE) Office of Industrial Technologies (OIT), software called Pumping System Assessment Tool (PSAT) is developed. This software is capable of assisting engineers and facility operators in evaluating the efficiency of the pumping systems facility in charged, based on pump and motor nameplate data and 3 other field measurements. It identifies energy saving opportunities in pumping systems and further quantifies the opportunities in both dollars and electrical energy savings. However, there is no solution provided, so the measures needed to improve the system have to be identified by other means.

Basically, there are two main types of pumps, namely centrifugal or dynamic pump and positive displacement pump. According to Esposito (2009), one of the difference between the dynamic pump and positive displacement pump is that the dynamic pumps provide smooth continuous flow and the output of its flow is reduced when the circuit resistance is increased. On the other hand, the positive displacement pumps provide a constant amount of fluid per revolution of the pump shaft, despite the changes on the system pressure. According to Rosen and Kandiah (2015), majority of the pumps used in the industrial sector and for heavy duty usage are the dynamic pumps, or to be more specific, the centrifugal pumps.

1.2 Problem Statement

According to Asimakopoulos et al. (2012), there are 30-45% of global energy demand which was the responsible of buildings. Among all, as stated by the Department of Energy and Climate Change (2013) and Chung and Rhee (2014), commercial buildings, primarily office and university buildings are the representation of the highest energy consumption buildings. Furthermore, based on Chung and Rhee

(2014), the energy conservation potential of university buildings ranges from 6 to 29 percent, which represent a huge potential of both energy and cost savings.

On the other hand, based on a research done by Almeida, Fonseca and Bertoldi (2003), while studying on the energy-efficient motor systems in the industrial and in the services sectors, they supported the importance of energy efficiency using the recent field characterization project backed by the European Union (EU). In the project, the finding shows that in industrialized countries, most of the electricity was supplied for electric motor applications.

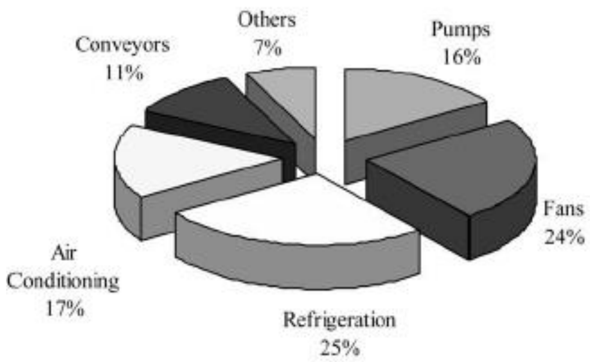

Figure 1.1 Disaggregation of motor electricity consumption by end-use in the services sector.

As shown in the figure above, the pumps consumed about 16% of the total motor electricity consumption in services sector in EU, which had the fourth largest share among all other electric motor applications. Of the energy consumed for pumping, approximately 75% of it is used for centrifugal pumps and the rest is account for positive displacement pumps. Hence by enhancing the energy efficiency of the centrifugal pumps alone, the energy use of the respective system would also be greatly impacted.

The Green Building of Technology Campus, UTeM, is an academic building with two pumps operating to supply adequate amount of water to thousands of people occupying the building every day except for weekends. Hence, energy consumption of this building should be undoubtedly high. In resolving this issue, every single effort counts. Since the energy consumed by the pumps contribute to the total energy consumption of the building, the efficiency of the pumps should be concerned as part of efforts of energy conservation.

1.3 Objective

The objectives of this project are as follows:

1. To investigate the water pumping system for energy saving opportunities.
2. To estimate the optimization rating of the current water pumping system with Pumping System Assessment Tool (PSAT).

1.4 Scope of Project

The scopes of this project are:

1. The study will be focused on the centrifugal pumps in the water pumping systems. Other types of pumps will not be considered.
2. The study will focus on the water pumping system of the Green Building of Technology Campus, UTeM.

1.5 General Methodology

The actions that need to be carried out to achieve the objectives in this project are listed as follow.

1. Literature review

   Journals, articles, handbooks or any materials regarding the project will be reviewed.

2. Data collection

   Readings of flow rate and operating time of a water pumping system will be collected for further analysis. Data on nameplate of pumps will also be collected.

3. Validation

   Validation will be done by statistical method. The minimum, average and maximum reading for power consumption are determined.

4. Simulation with PSAT

   Simulation will be performed to obtain rating on how much the current water pumping system can be optimized for the purpose of energy efficiency.

5. Report writing

   A report on this study will be written at the end of the project.

The methodology of this study is summarized in the flow chart as shown in Figure 1.2.

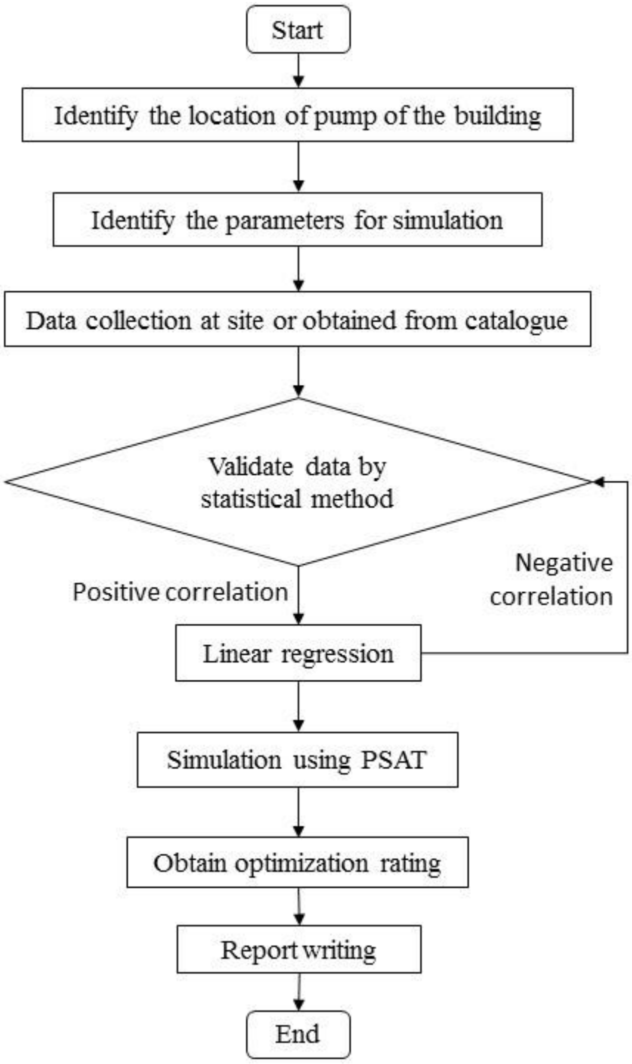

Figure 1.2 Flow chart of methodology.

In this report, there are five written chapters, covering from Introduction to Conclusion and Recommendation for Future Research. Chapter 1 contains a brief introduction about the importance of energy efficiency in water pumping systems. Moving forward to Chapter 2, it is a record of findings of previous effort being put in defining the terms and determining the cause and solution for the topic. Proceeding to Chapter 3 is the experimental methods planned to be carried out to obtain the data required. The collection of data is then being recorded in Chapter 4 together with the analysis of these data. Finally, in Chapter 5, there would be a conclusion drawn for this project and recommendations are suggested.

CHAPTER 2

LITERATURE REVIEW

2.1 Energy

According to Tenne-Sens (2009), energy, together with matter, are two of the fundamental constituents of the universe. All physical processes involve the exchange of energy or conversion of one of its named form to another, including relativistic mass-energy conversion. However, the total energy of a closed system is a conserved quantity. The most familiar forms of energy known are in the form of mechanical work and heat transfer, while other forms include electrical, kinetic, potential, and the list goes on.

The word 'energy', is originally derived from a Greek word 'ενέργεια', which means 'inner work'. This is intuitively reasonable as all of the physical labor of human expends the body's energy. The intuitive notions of energy and its related parameters were first quantified with Newton's three laws of motion:

1. Every object persists in its original state of motion, be it in its state of rest or uniform motion in a straight line if no external forces are applied.
2. Force is equal to mass times acceleration. Or in other words, it is equal to the change in momentum per change in time.
3. Every action has an equal or opposite re-action.

Power, on the other hand, is the rate at which work is performed or be defined as the rate at which energy is expended. (Water Environmental Federation, 2009) All power units are measured in work per unit time with no exception. While in the Merriam-Webster Online Dictionary, the term power means a source or means of supplying energy. It is also the rate of time at which work is done or energy is emitted or is transferred.

Meanwhile, according to Water Environmental Federation (2009), the term 'energy' is defined as the ability or capacity to do work. It can be changed from one form to another but cannot be created nor destroyed, which conform to the definition made earlier in the encyclopedia. However, in water and wastewater facilities, the most common form of energy used is electrical energy. Besides, it states that the total energy consumption is the product of the power applied and the amount of time of the power applied:

$$\text{Energy (kWh)} = \text{Power (kW)} \times \text{Time (hr)} \qquad (1)$$

The International System (SI) unit of energy is the joule (J), the product of power and time (kWh), if it is consumed as electricity.

The consumption of energy worldwide is increasing at a very fast pace but the available resources still remain limited. According to Morvay and Gvozdenac (2008), there is a 2% increase at the global need for energy per year. This figure may not sound like much, but it represents almost a doubling of energy consumption over a period of thirty years. While it is commonly agreed that the main cause of climate change is human activity, the high consumption of energy would be the best evidence of the statement. Apart from environmental impact, the high energy consumption would contribute to high energy cost, and hence, decrease the profitability of the organization. It is common knowledge that all but renewable energy sources are depletable, hence energy prices will continue to grow undoubtedly when energy shrinks.

Due to the awareness of economic and environmental impact brought about by high energy consumption, organizations around the world are striving to reduce it. Both Morvay and Gvozdenac (2008) and Jayamaha (2007) agree that energy