FOUR SEASON HYBRID POWER SYSTEM TARGETING USING POWER PINCH ANALYSIS

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To my beloved parents,
Azman Bin Ismail and Patimah Zahuran Binti Mohd Nor,
for the encouragement and blessing all time as well as to
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Professor Sharifah and Dr. Ho Wai Shin
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ABSTRACT

Energy exists in many different forms in nature but the most effective usage to human is electrical energy. Typically, electricity demand is higher in the winter than in the summer. Demand for electricity tends also to fluctuate over the course of the day, determined by human activity. This resulting in inefficient energy operation for the countries involved. Pinch analysis is a rigorous, structured approach for identifying inefficiencies in industrial process energy use. Power Pinch Analysis (PoPA) is an extension of the heat Pinch Analysis (PA). PoPA is used for the optimal Hybrid Power System (HPS) supply planning and demand management. This project involved the extended usage of PoPA in seasonal energy production planning. The result expected from this modelling study is successful of PoPA in order to tackle the optimization problem in energy production. As for the long term energy storage, it is necessary for the HPS in order to overcome problems in high energy demand seasons.

ABSTRAK

Tenaga wujud dalam pelbagai bentuk dalam alam semula jadi tetapi penggunaan yang paling efektif untuk manusia adalah tenaga elektrik. Biasanya, permintaan elektrik adalah lebih tinggi pada musim sejuk berbanding musim panas. Permintaan untuk tenaga elektrik juga tidak menentu sepanjang hari, berdasarkan aktiviti manusia. Ini menyebabkan operasi tenaga yang tidak cekap bagi negara-negara yang terlibat. Analisis jepit adalah kukuh, pendekatan berstruktur untuk mengenal pasti ketidakcekapan dalam penggunaan proses tenaga dalam industri. Analisis kuasa jepit (PoPA) adalah lanjutan daripada Analisis haba jepit (PA). PoPA telah menyelesaikan perancangan bekalan system bekalan hybrid optimum (HPS) dan pengurusan permintaan. Projek ini melibatkan penggunaan lanjutan Popa dalam pengeluaran tenaga bermusim. Hasil dijangka daripada kajian model ini adalah kejayaan PoPA bagi menangani masalah pengoptimuman dalam pengeluaran tenaga. Untuk simpanan jangka masa panjang, adalah menjadi keperluan untuk HPS di negara bermusim untuk menangani masalah ketidakcukupan tenaga semasa musim yan memerlukan tenaga yang banyak.

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LIST OF ABBREVIATIONS

PoPA	-	Power Pinch Analysis
ESCA	-	Electric System Cascade Analysis
PV	-	Photovoltaic
CSP	-	Concentrating Solar Power
PA	-	Pinch Analysis
CAES	-	Compressed Air Energy Storage
PHES	-	Pump Hydro Energy Storage
kWh	-	kilowatt hour
RPM	-	Rotation Per Minute
AC	-	Alternating Current
DC	-	Direct Current

LIST OF SYMBOLS

$DC_{s/d}$	-	DC electricity surplus/deficit
$AC_{converted}$	-	amount of DC converted from AC electricity surplus
$DC_{converted}$	-	amount of DC electricity surplus that will be converted to AC to satisfy the AC load demand
S_t	-	Storage capacity
S_{t-1}	-	Storage capacity at previous time interval
σ	-	Hourly self-discharge rate
t	-	Time
T	-	Duration of time
η_I	-	Inverter efficiency
η_d	-	Discharging efficiency of storage
C_t	-	Charging quantity
η_C	-	Charging efficiency
$	-	United States Dollar

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Energy is the basic necessity for the economic development of a country. There are many functions necessary to present-day living disturbed if the supply of energy stops. It is practically impossible to estimate the actual magnitude of the part that energy has played in the building up of present–day civilisation. The availability of huge amount of energy in the modern times has resulted in a shorter working day, higher agricultural and industrial production, and better transportation facilities. There is a close relationship energy used per person and his standard of living. The greater the per capita consumption of energy in a country, the higher is the standard of living of its people.

Energy exists in many different forms in nature but the most effective usage to human is in form of electrical energy. The modern society is so much relying to the use of electrical energy until it has become a part and parcel of daily life. By current technologies, it is possible to convert electrical energy into any desired form. This has given electrical energy a place of one of the pride in the modern world. The survival of industrial projects and our modern social life depends primarily upon low cost and uninterrupted supply of electrical energy.

Typically, electricity demand is higher in the winter than in the summer. The peak demands in the summer are usually lower when compared to the peak demands of the winter and the low demands of the summer are low when compared to the low demands of the winter. Demand for electricity tends also to fluctuate over the course of the day, determined by human activity.

Human activity, which mainly measured in residential sector contributes most to the higher demand during winter compared to summer. This is because, during winter, people return home they will be turning on electrical equipment such as heater, lighting, televisions, and kettles and begin to start cooking dinner. Demand then begins to fall and drops off as people begin to retire to bed. Meanwhile, during summer, people return home when it is still light and perhaps a preference for cold beverages/food in the warmer weather. During evening, the household electricity use being lower in the summer because every usage at home in the evening will be counteracted by the switching off of air conditioning systems in shops and offices.

1.2 Research Background

A Hybrid Power System (HPS) is a system that combines the use of intermittent electrical energy from various Renewable Energy (RE) sources including solar photovoltaic, wind, wave, biomass and geothermal with “purchased” or outsourced power that are either supplied from the grid or self-generated onsite using conventional fuel sources. The HPS is more suitable for industrial applications as compared to using individual RE that can either be too dependent on one RE source (e.g. in the case of biomass), or cater for small loads (i.e. in the case of solar). Less risk is taken by using HPS. The HPS is a step on tackling the problems facing by many countries in order to meet the demand of its user.

The energy usage for seasonal countries is not the same for each season. The difference in energy consumption during seasons will make the cost of electricity production to rise. This results in inefficient energy operation for the countries involved. Usually the countries that have four seasons will have trouble during the season of higher demand. Thus, this contributes to high electricity prices and higher risk of global warming.

Hence, a cost effective storage can be used to store energy produced in one season to be used later in higher demand season. PoPA is used in this study to cater the energy demand in four season country.

1.3 Problem Statement

Given a set of demands and renewable energy sources which have different electricity profiles at different seasons, it is desired to determine the type and size of power storage and backup generator, as well as the potential mechanism of storing and utilisation of electricity to obtain the cost effective minimum outsource electricity target considering grid connected system.

Power pinch analysis has been previously developed in order to tackle the problem of energy production but its usage has been limited to the analysis of one season country only. This research extends the usage of PoPA for seasonal countries analysis in order to tackle the fluctuation problems of energy production.

1.4 Research Objective

Based on the problem statement, finding the way to tackle the energy demand is crucial. Followings are the objectives of the research:

(1) To develop extended power pinch analysis to cater for four season country.

(2) To evaluate the appropriate long term seasonal storage system using PoPA

(3) To evaluate the economics if hydrogen generated from RE should be stored and used in other seasons or sold for other purposes.

1.5 Research Scope

The scope of the research simplified below:

(1) State of the art review on power pinch analysis as well as the seasonal power sources and demands behaviour.

(2) Developing step wise methodology for extended power pinch analysis for four season country.

(3) Applying case study for seasonal country on the extended power pinch in order to find outsource energy and others.

(4) Performing economic analysis on the system.

1.6 Significance of the Research

This research will contribute to electricity saving and reducing its cost during high demand season. Also, the research is important for the country with four seasons to implement the suggested way based on the findings.

Also, the research can contribute to the extended knowledge of pinch analysis due to extended usage of power pinch analysis that is currently only on one season country. The research will contribute to the birth of expert in power pinch analysis on four season country.

1.7 Report Outline

This report is divided into four chapters. Chapter One covers the introduction part of the project. This chapter also consist of six sub-chapters which is introduction, research background, problem statement, objectives, scope of the project and report outline. Chapter Two is a literature review on the Energy demand overview, renewable energy and energy storage. Besides that, it also shows the introduction of power pinch analysis method.

Next, Chapter Three is about methods and process of the project. The steps taken in this project is discussed and explains the assumptions and limitations of the research conducted. Then, Chapter Four is the result and discussion of the project.

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