OPTIMAL MIX OF RENEWABLE AND CHP GENERATIONS FOR REDUCED EMISSIONS

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A project report submitted in fulfillment of
the requirements for the award of the degree
of Master of Engineering (Electrical-Power)

Faculty of Electrical Engineering

Universiti Teknologi Malaysia

JANUARY 2012

Dedicated to my beloved family and office

ACKNOWLEDGEMENTS

In preparing this thesis, I was in contact with many engineering professionals and manufactures. Everyone has contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my thesis supervisor, Dr. Mohamed Abd El-Moneim Shaaban, for continuous encouragement, guidance and friendship.

My sincere appreciation also extends to my beloved wife and children for their sacrifice and emotional support to me during the years of study.

I would also like to thank my office, Ranhill WorleyParsons Malaysia, all my friends and colleagues who have provided assistance at various occasions.

ABSTRACT

The demand for electrical energy grows exponentially over time and most of electrical power generation is produced from fossil fuel. The increase in fossil fuel utilization results in excessive greenhouse gas emission to environment which paves way for global warming and natural disasters. The United Nations Framework Convention on Climate Change (UNFCCC) guides the global community on utilisation of emission-free renewable energy. Stochastic nature of wind renewable energy is not promising in emission reduction while operating in parallel with central power generation. As an alternative this report is developed to integrate the uncontrolled wind / renewable power with distributed generation. Several previous research works qualify the feasibility on integration of renewable and fossil fuel power generation at a remote network / distributed generation (DG). However in practice distributed generations exist with cogeneration/combine heat & power generation (CHP) to utilize the heat while producing electricity to attain maximum fuel utilization. This maximum fuel utilization increases system efficiency and reduces the emission. For further emission reduction from CHP, this report suggests a new concept. The new concept proposes integration of CHP with renewable power generation. As part of this report, a scenario is evaluated where wind power integration with a reciprocating engine CHP is carried out. Considerable emission reduction is obtained from the integration model. For evaluation of this new integration concept with the other type of CHPs and other than wind renewable, an algorithm is presented as part of this report.

ABSTRAK

Permintaan terhadap tenaga elektrik bertambah dari semasa ke semasa dan kebanyakan penjanaan tenaga elektrik yang dihasilkan adalah daripada bahan api fosil. Peningkatan dalam penggunaan bahan api fosil mengakibatkan emisi gas rumah hijau yang berlebihan kepada persekitaran dan ini menjadi penyumbang utama kepada pemanasan global dan bencana alam. "United Nations Framework Convention on Climate Change" (UNFCCC) memberi garis panduan kepada masyarakat global terhadap pengunaan tenaga boleh diperbaharui yang bebas daripada emisi gas rumah hijau. Berdasarkan beberapa kajian yang telah di jalankan, penggabungan janakuasa elektrik menggunakan bahan api fosil dan tenaga angin yang bersifat stokastik di Pusat janakuasa utama tidak dapat menjamin pengurangan emisi. Sebagai alternatif, laporan ini disediakan untuk mengkaji peluang untuk mengintegrasi janakuasa menggunakan tenaga angin bersama stesen janakuasa persendirian /'distributed generation'. Kerja- kerja penyelidikan sebelum ini menumpukan akan kesesuaian penggabungan tenaga boleh diperbaharui dengan penjana kuasa yang menggunakan bahan api fosil di kawasan pedalaman atau 'distributed generation' (DG). Walau bagaimanapun, secara lazimnya, penjanaan kuasa dibangunkan dengan penjanaan bersama / gabungan tenaga haba & jana kuasa (CHP) yang menggunakan haba bagi menghasilkan tenaga elektrik bagi mendapatkan penggunaan bahan api yang maksimum. Pengunaan bahan api yang maksimum akan meningkatkan kecekapan sistem dan mengurangkan emisi. Laporan ini mencadangkan satu konsep baru bagi mengurangkan lebih banyak emisi daripada CHP. Konsep baru ini mencadangkan gabungan CHP dengan tenaga boleh diperbaharui. Salah satu senario yang diambil kira dalam laporan ini ialah integrasi tenaga angin dengan salingan enjin CHP. Dari model baru yang dicadangkan, pengurangan emisi gas rumah hijau telah berjaya

diperolehi. Laporan ini turut mencadangkan konsep integrasi baru ini dinilai melalui kaedah algoritma selain daripada pengunaan jenis CHP yang lain dengan gabungan tenaga boleh diperbaharui yang lain (selain dari angin).

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LIST OF SYMBOLS/ABBREVIATIONS

Btu	British thermal unit
C	Carbon
CCGT	Closed Cycle Gas Turbine
CDM	Clean Development Mechanism
CH_4	Methane
CHP	Combined Heat and Power
CO_2	Carbon dioxide
COEF	Carbon Emission Co-efficient Factor
CSP	Concentrating Solar Power
DG	Distributed Generation
GHG	Green House Gas
GTG	Gas Turbine Generator
HRSG	Heat Recovery System Generators
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
Kcal	Kilo calories
Kg	Kilogram
kgC	Kilogram Carbon
KLCC	Kuala Lumpur Convention Centre
kW	kilowatt

kWh	kilowatt–hour
m/s	meter per second
MW	Megawatt
NOx	Nitrous oxide
OCGT	Open Cycle Gas Turbine
PMSG	Permanent Magnet Synchronous Generator
ppmv	parts per million by volume
RES	Renewable Energy Source
SO_2	Sulphur dioxide
tC	ton carbon
tCO_2	ton carbon dioxide
TJ	Tera joule
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
VA	Volt-ampere
Yr	year

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CHAPTER 1

INTRODUCTION

1.1. Background of Study

As global population and economy grows, the demand for electrical energy increases exponentially [1]. Presently electrical power generation is mainly from fossil fuels such as coal, oil and natural gas across the world. This fossil fuel type power generation is identified as one of the major contributors for the greenhouse gas (GHG) emission [2].

The emitted GHG causes global warming and in turn creates natural disasters. GHG emission reduction is a global challenge to protect the world.

Every country is working towards reducing the emission without compromising on their country's economic growth. The international body United Nations Framework Convention on Climate Change (UNFCCC) guides the global community to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system [3].

To aid the emission reduction challenge, the electricity has industry identified multiple opportunities at power generation side and utilisation side, with the objective to reduce the dependency on fossil fuel. In this report, an opportunity at the power generation side is identified and named as integration generation concept. This integration concept is a combination of well-known renewable energy source (RES) and cogeneration. Cogeneration is used to refer as Combined Heat & Power (CHP).

In general RES power generation is considered as green power generation or greenhouse gas-free during operation. Multiple RES generation technologies exist globally. Among all renewable energy power generation technologies Solar and Wind energies are predominantly established and constitute a considerable amount of global power generation. This report is developed based on wind power, however, a new algorithm is developed to integrate any type of renewable energy resource with cogeneration power to reduce emissions.

Power generation from wind is uncontrolled due to the nature of wind. Wind availability varies over time and hence wind power generation always is considered to operate with other reliable base power generation system. Fossil fuel is one of the

reliable power generations. But existing studies show that operating wind power in parallel with dispatchable fossil fuel power generation grid does not contribute much to emission reduction unless the available wind power is curtailed to operate the fossil fuel power generation grid at its maximum possible efficiency.

The power generation penetrations of wind will directly affect the power quality of the system. Higher wind penetration may even cause the system to become unstable. Thus it is necessary to test the highest penetration of wind in an isolated system although the more utility of wind power the more fuel savings [4].

Wind power requires a large backup capacity. As a rule, this is uneconomic and tends to limit the potential share of wind power in the power grid to the amount of mobile reserve capacity. This is in contradiction to fuel efficiency. On the other hand, wind power is effective in areas reliant on decentralised power with expansive fuel [5].

As part of this report, it is considered to operate the non-dispatchable wind power in parallel with dispatchable power generation at the distribution system level as opposed to the previous proposals of operating wind power in parallel with a central power grid system. Also this report considered to utilise almost all the power produced by the wind generation.

The concept of distribution level power generation is getting popularised globally due to the opportunity to improve the system efficiency. The improved efficient

system is achieved by using the heat that is always generated when electricity is generated. It increases the overall fuel efficiency of the plant [6]. This distribution level power generation is referred as distributed generation (DG). DG system promise to have the power generation next to the load or demand centre, eliminates long transmission lines, infrastructure and line losses. Increased system efficiency is directly proportional to reduction in GHG.

In the distributed generation, it is always recommended to have a CHP system to utilise the heat produced during the power generation. CHP technologies are globally proven technology and exist over several years. The heat from CHP units are utilised in the form of hot water, steam or for space heating and/or cooling application. This report considered to use CHP unit at distributed power generation with the assumption of a demand exists for power and heat at the selected distributed generation installation location.

At some of the distributed generation, interconnection with electricity distribution network is found as backup power or to export power from the distributed generation. However in this report a distributed power generation operates as a stand-alone power generation and no interface with electricity distribution network.

The power generated from CHP and wind is combined together in this report to produce an increased efficiency system with the objective to reduce the emission from power generation. Consider a high efficiency system consists of cogeneration and wind power generation at a distributed generation system. This report is prepared based on

exiting technology equipment and is not recommended for design changes in the equipment internal design or configuration.

The challenge at the increased high efficiency system is the selection of wind power generation capacity or renewable energy power generation capacity with respect to the cogeneration capacity and to achieve the emission reduction from the cogeneration system by utilising the produced wind power / renewable energy and by reducing the amount of fossil fuel burnt.

In general emission reduction refers to greenhouse gas (GHG) reduction. GHG predominantly emanates from the energy sector fossil fuel combustion. This GHG consists of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_X). Among these emitted gases CO_2 accounts typically for 95 precent [7]. In this report considered the reduction in quantitatively much more component CO_2 as emission reduction.

For the emission estimation multiple, metrics exist. In this report the formulas considered as given by the international community, Intergovernmental Panel on Climate Change (IPCC) guidelines for National Green House Gas inventories. IPCC was established by United Nations Organizations and recognized as the most authoritative scientific and technical voice on climate issues globally.

1.2. Objectives of the Study

The objectives of this report are:

a) To select a CHP suitable to operate in parallel with renewable wind power
b) To size the renewable wind power installed capacity to operate in parallel with the selected CHP.
c) To estimate the emission reduction by the integration of renewable wind power and CHP
d) To investigate for renewable energies other than wind power for integration with CHP and to estimate emission reduction.

1.3. Problem Statement

Finding an opportunity to reduce the greenhouse gas emission from electrical power and heat generation industry, since the emission from these industries globally constitute 24% of the green houses emitted from various human activities. Figure 1.1 shows the GHG emission from various industries globally.

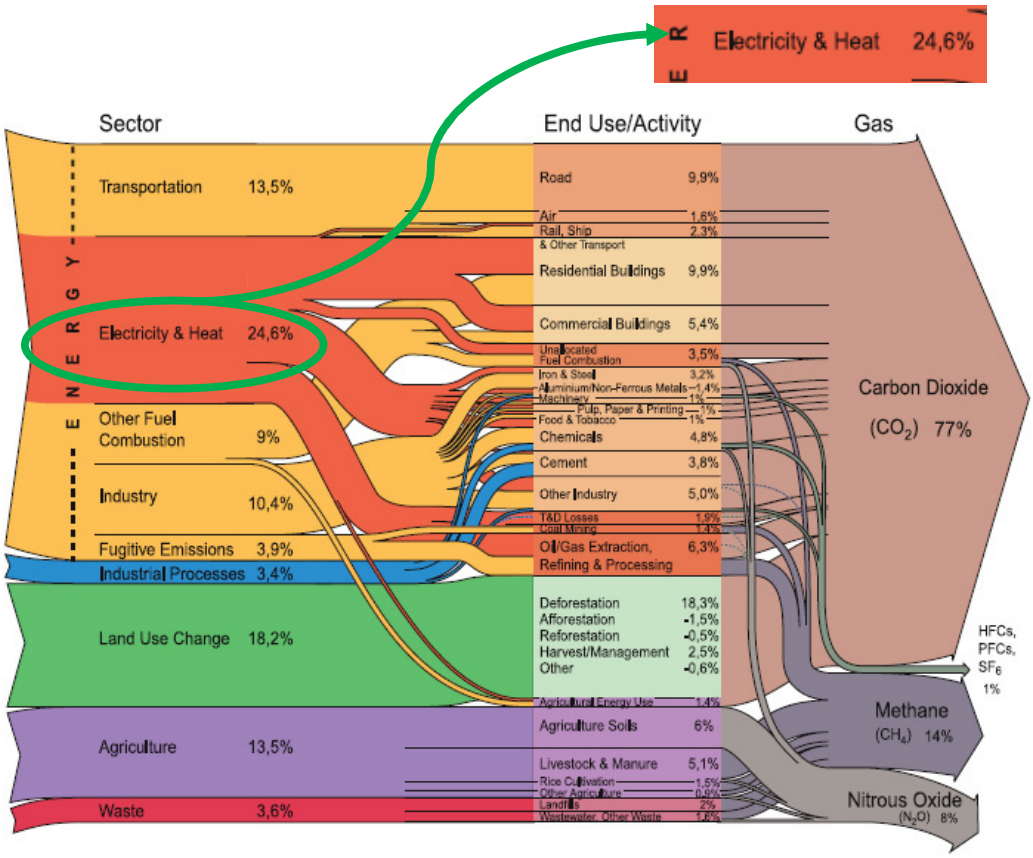

Figure 1.1: World Greenhouse Gas Emission by sector

Also to make wind renewable energy more attractive to be implemented over its uncontrolled behaviour constrain.

1.4. Scope of Study

In the present global market multiple type /models of CHP / Cogeneration power plant technology exists such as steam turbine CHP, Gas Turbine CHP, Reciprocating

engine CHP, etc. To establish the selection criteria for selecting a specific CHP type suitable to operate in parallel with wind power is one of the scopes of this report.

Next to CHP selection is to establish a formula for wind turbine installed capacity selection. Usually wind turbine selection is based on wind availability, land availability, economics, wind turbine technology availability, etc. However in report selection of wind turbine capacity based on the achievable emission reduction from CHP while operating the wind turbine in parallel with the CHP.

Followed by CHP type selection and Wind turbine installed capacity selection, the scope covers developing a scheme or equipment configuration for the wind and CHP integration concept. During the presence of wind power, to accommodate the wind power CHP operates at part load which results in reduction in power as well as heat output from the CHP. The reduction in power is compensated by the wind turbine, whereas reduction in heat from CHP needs to be substituted by additional heating facility to meet the demand. Assumed electrical power and heat demand are constant at the selected installation for this report.

Followed by identifying the formulas for emission reduction is part of this report. These formulas constitute multiple factors and constants based on the type of fossil fuel and burning application and the country where the installation is made. This report aims to present formulas, associated factors and constants for all the fossil fuel used at power and heat application and for most of the countries, extracted from International Energy Agency (IEA) data tables.

The final scope of this report is to develop an algorithm / step by step procedure to rationalise this study with respect to other renewable energy sources, in addition to the wind, integration with cogeneration power plant for emission reduction.

1.5. Report Outline

This report is divided into six chapters. Chapter 1 is the introduction to the project. Brief description of the project is stated where the objective of study, problem statement and scope of the study are mentioned.

Chapter 2 covers a literature survey of this report. The main topics discussed are wind power, distributed generation & renewable, cogeneration, greenhouse gases and emission estimation.

Chapter 3 covers the methodology that has been adopted to select the integration concept power & heat generation equipment and emission estimation.

Chapter 4 presents a calculation and the result of this project report for a hypothetical scenario.

Chapter 5 presents the analysis and discussion based on real time scenario.

Lastly, chapter 6 presents the conclusion of this research /project report. Future work and recommendations are also presented.

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