

DEVELOPMENT OF SMALL STIRLING ENGINE GENERATOR

A report submitted to Faculty of Electrical Engineering, Universiti Teknologi MARA
in partial fulfillment of the requirement for Bachelor of Electrical Engineering (Hons).

**Project report presented in the partial fulfillment for the award of the
Bachelor of Electrical Engineering (Hons)
UNIVERSITI TEKNOLOGI MARA**

This thesis is approved by



Pn. Khairul Safuan Bin Muhammad
Project Supervisor
Faculty of Electrical Engineering
Universiti Teknologi MARA (UiTM)
40450 Shah Alam
Selangor.

Date: 12/10/2023



MUHAMAD FIKRI BIN MUHAMAD HALIL

**Faculty of Electrical Engineering
UNIVERSITI TEKNOLOGI MARA
40450 SHAH ALAM, SELANGOR**

ACKNOWLEDGEMENTS

In the name of Allah, the Beneficent, the Merciful. All praise is to Allah who has given me the strength and ability to complete this project and the thesis as it is today. All perfect praises belong to Allah SWT, Lord of the universe. May His blessings upon the Prophet Muhammad SAW, and members of his family and companions.

I want to take this opportunity to express my appreciation to my supervisors, En. Khairul Safuan Bin Muhammad and En. Ahmad Hussein bin Abd. Hamid for their thought and patience in helping me by providing a lot of information and advice in order to complete this research.

Then, I wish to thank to all supporting UiTM staff especially to all technicians machining laboratory at Fakulti Kejuruteraan Mekanikal for their suggestions and support on this project. Their comments on this project are greatly appreciated.

Most importantly I would like to extend my appreciation to my parents for their support and patience during my pursuit for higher studies. They have encouraged me throughout my education, and I will always be grateful for their sacrifice, generosity and love.

Muhamad Fikri Bin Muhamad Halil

Faculty of Electrical Engineering

Universiti Teknologi Mara (UiTM)

Shah Alam, Selangor Darul Ehsan

ABSTRACT

This paper describes the basic concepts and principles of designing small Stirling engine generator. Stirling engine generator is a mechanical device that converts heat energy into electrical energy. This engine operates on a closed regenerative thermodynamic cycle, with cyclic compression and expansion of the working fluid at different temperature level [1]. Compare to ordinary fuel engine which is internally combustion, Stirling engine is external combustion engine type where the heat source is constantly supplied. The purpose of this study is to design and build small Stirling engine equipped with alternator to produce electrical output (Alternating Current power). The power output will be roughly estimated and measured at every stage of conversions. The Stirling engine built is gamma type with double heat cylinder and air is used as its working fluid. This engine produce mechanical output through flywheel and alternator is mounted on it. The alternator built is axial flux permanent magnet generator (PMG) type. The magnets used to induce current are neodymium magnet (NdFeB), the most powerful magnet on earth [2]. Power output (mechanical) from the Stirling engine will be estimated using Beale formula while alternator power output (electrical) will be estimated based on Faraday's Law.

TABLE OF CONTENTS

CHAPTER	DESCRIPTION	PAGE
	Declaration	ii
	Acknowledgements	iii
	Abstract	iv
	Tables of contents	v
	List of figures	vii
	List of tables	viii
	Abbreviations	ix
1.	INTRODUCTION	
	1.1 Background	1
	1.2 Objective of Project	2
	1.3 Thesis Organization	2
2.	THEORY AND LITERATURE REVIEW	
	2.1 Stirling Engine	
	2.1.1 History	4
	2.1.2 General principles	5
	2.1.3 Mechanical configurations of Stirling engine	6
	2.1.4 Stirling engine cycle operations	8
	2.1.5 Small Stirling engine design method	12
	2.2 Axial Flux PMG	
	2.2.1 Background	17
	2.2.2 PMG configurations	18
	2.2.3 Axial flux PMG constructions	19
	2.2.4 Permanent magnet arrangement	21
	2.2.5 Coil wiring in stator	22
	2.2.6 Faraday's law	24

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

This chapter will discuss the objective of the project or thesis and the organization of the thesis. It can help students to obtain the basic knowledge of principle and operation of Stirling engine generator and to experience the fabrication and construction of small Stirling engine generator. The thesis also help student to learn the theory and how to fabricate and develop the small Stirling generator model. This chapter also helps students to know the flow of the thesis.

Recently, the consumption of coal, oil, natural gas or even nuclear in most electric power plants has create serious environmental issues such as global warming and air pollution. Furthermore, those resources are non-renewable and nearly depleted. Therefore, solar energy has greatest potential to become future renewable resources [3]. Solar energy can be converted into electrical energy through photovoltaic and heat engines. Photovoltaic has main weaknesses, which is the generation system is not available during night-time. Contradict to photovoltaic, heat engines (Stirling engine) can be operated all of the times due to the flexibility of the heat source. This means that, with an additional burner, the required heat can also be obtained using fossil fuels (Biogas, etc..). Thus, the systems continuously generate electricity with or without solar energy.[1] Furthermore, modern Stirling engine generator is capable to convert sun power into electrical power up to 40% efficiency rather than photovoltaic system which has efficiency between 15-18% [3].

The Stirling heat engine was first patented in 1816 by Robert Stirling. Since then, several Stirling engines based on his invention have been built in many forms and sizes [1]. In solar power generation system, the solar radiation is converted to electricity in three