ECONOMIC FEASIBILITY OF A HYBRID ENERGY SYSTEM FOR KALPITIYA PENINSULA FROM SELECTED TECHNOLOGIES

K. R. Atapattu

(158275F)

Degree of Master of Engineering

Department of Mechanical Engineering

University of Moratuwa
Sri Lanka

March 2020

ECONOMIC FEASIBILITY OF A HYBRID ENERGY SYSTEM FOR KALPITIYA PENINSULA FROM SELECTED TECHNOLOGIES

Kavinda Rukshan Atapattu

(158275F)

Thesis submitted in partial fulfillment of the requirements for the degree
Master of Engineering

Department of Mechanical Engineering

University of Moratuwa
Sri Lanka

March 2020

DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: ..... Date: .....

K.R.Atapattu

The above candidate has carried out research for the Masters thesis under my supervision

Signature: ..... Date: .....

Prof. R.A Attalage

ABSRACT

Economic feasibility of having a grid connected hybrid energy system, consist of wind, solar, biomass (rice husk) & municipal solid waste (MSW) technologies for Kalpitiya peninsula was studied. Four (04) different microgrid configurations were simulated in HOMER Pro(Hybrid Optimization of Multiple Electric Renewables) for a project life time of 20 years and the economics of each case was compared with the base case, where Kalpitiya peninsula is fed from fossil fuel based (i.e.: diesel) power transmitted through main utility grid. Electricity demand data of Kalpitiya peninsula in every 30 minute interval throughout a day were obtained for the days in calendar year (2018) from Puttalam grid substation (feeder 03) to derive averaged hourly load profile and to study the daily, monthly variation. Average electricity demand in April was found to be the highest of all months in the year and average load in a typical day was 125056.52 kWh with a daily maximum of 8320.5 kW. Considering the recent global market costs trends of installation, operation and maintenance of renewable energy resources as well as the availability of resources, in Sri Lankan context four (04) different configurations of microgrids were simulated in HOMER Pro with the motive of ensuring 100% power supply throughout the project lifetime of 20 years. Most economical option in a private investors' perspective was a microgrid with wind, solar, biomass (rice husk) & municipal solid waste (MSW) in the system which has a discounted payback period of 2.68 years. However, in the perspective of Ceylon Electricity Board, the most economical microgrid consist of wind, solar & biomass (rice husk), where annual cost saving against the base case of LKR 350.5 Mn equivalent to 'stop running' a 1 MW diesel generator for 353 days per year. Sensitivity analysis was performed limiting the grid sales for each microgrid configuration proved that net energy purchase was lowest when the grid sale capacity was 10000 kW. Any of microgrid combinations was not possible to operate in island mode due to the intermittency of renewable resources. However, it was evident that none of the configurations considered solar energy is significant due to the high dominance in wind, biomass & MSW resources.

Key words: Kalpitiya, Microgrid, Renewable energy, HOMER Pro

ACKNOWLEDGEMENT

It is with a great pleasure of expressing my gratitude to all the people who gave me a lot of help throughout this research.

I must honourably mention my supervisor Prof. Rahula A. Attalage (Former Deputy Vice Chancellor, University of Moratuwa), for the valuable guidance, kind hearted co-operation and encouragement extended for making this research meaningful.

I would be pleased to mention with a great respect Dr.H.K.G. Punchihewa, Course coordinator for M.Eng in Energy Technology - Intake 11 & Head of the Department of Mechanical Engineering-University of Moratuwa, for inspiring & assisting me throughout the whole M.Eng programme. I wish to thank all the lecturers in Department of Mechanical Engineering & all the visiting lecturers who made us prepared with knowledge to make this a success. I would like to pay my gratitude for especially for Eng.A.N.G.A.B. Jayasinghe, Eng.A.R.M.U.E. Abeyrathne, Eng. W.A.M.L. Wasala, who were a great helping hand in resolving the issues & all the colleagues who assisted me in numerous ways with immense generosity over their valuable time.

I must gratefully mention the Eng. W.J.L.D.I. Wickramasighe, Eng.Chulaka Eng. Subhan and the staff members of Ceylon Electricity Board at Puttalam grid substation for assisting me to obtain the load demand data.

I wish to thank Mr. S.D.L. Sandanayake, & all non-academic staff members in the Department of Mechanical Engineering, and University of Moratuwa for helpful & friendly co-operation during the M.Eng programme. At last but not the least I would like to pay my sincere gratitude to my dear parents, loving wife & other members in my family for the scarification & giving me the fullest support at all times in making this effort a success.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

LIST OF ABBREVIATIONS

Abbreviation	Description
AC	Alternating Current
AGC	Automatic Generation Control
AWLR	Average Weighted Lending Rate
CAIDI	Customer Average Interruption Duration Index
CAIFI	Customer Average Interruption Frequency Index
CEB	Ceylon Electricity Board
CCM	Continuous Conduction Mode
DCM	Discontinuous Conduction Mode
DC	Direct Current
DER	Distributed Energy Resources
DG	Distributed Generator / Distributed Generation
GHI	Global Horizontal Irradiation
GSC	Grid Side Convertor
HOMER	Hybrid Optimization of Multiple Electric Renewables
IEEE	Institute of Electrical and Electronics Engineers
IRENA	International Renewable Energy Agency
JICA	Japan International Cooperation Agency
LCLTGEP	Least Cost Long Term Generation Expansion Plan
LCOE	Levelised Cost of Energy
LDC	Load Duration Curve (LDC)
ERCOT	Electric Reliability Council of Texas
LSC	Load Side Converter
LVPP	Lakvijaya Power Plant
MEM	Microgrid Energy Manager

MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MPPT	Maximum Power Point Tracking
MSW	Municipal Solid Waste
NASA	National Aeronautics and Space Administration
NCRE	Non-Conventional Renewable Energy
NPC	Net Present Cost
NREL	National Renewable Energy Laboratory
NSSWM	National Strategy on Solid Waste Management
ORE	Other Renewable Energy
PC	Point of Connection
PCC	Point of Common Coupling
PI	Proportional Integral
PMS	Power Management Strategy
PUCSL	Public Utilities Commission of Sri Lanka
PV	Photovoltaic
PWM	Pulse Width Modulation
RDF	Refuse Derived Fuel
RSC	Renewable Side Converter
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SLSEA	Sri Lanka Sustainable Energy Authority
SSC	Storage Side Converter
SWM	Solid Waste Management
USA	United States of America
VSC	Voltage Sourced Converter

LIST OF APPENDICES