THE ECONOMIC ANALYSIS FRAMEWORK
OF POTENTIAL DEVELOPMENT SOLAR PV
ENERGY IN MALAYSIA

MOHD FAUZI BIN MOHAMAD YUSOF

MASTER OF ENGINEERING IN ELECTRICAL
UNIVERSITI MALAYSIA PAHANG
SUPERVISOR’S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Engineering Electrical.

Signature

Name of Supervisor: DR ABU ZAHARIN AHMAD
Position: HEAD OF PROGRAMME (ELECTRICAL)
Date: DECEMBER 2014
STUDENT’S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature:
Name: MOHD FAUZI BIN MOHAMAD YUSOF
ID Number: MEE11004
Date: DECEMBER 2014
TABLE OF CONTENTS

SUPERVISOR’S DECLARATION ii
STUDENT’S DECLARATION iii
ACKNOWLEDGEMENTS iv
ABSTRACT v
ABSTRAK vi
TABLE OF CONTENTS viii
LIST OF TABLES xiii
LIST OF FIGURES xiv
LIST OF SYMBOLS xvii
LIST OF ABBREVIATIONS xix

CHAPTER 1 MOTIVATION

1.1 Introduction 1
1.2 Motivation 3
1.3 Problem Statement 10
1.4 Objectives 11
1.5 Scope 11
1.6 Thesis Outline 11
CHAPTER 2  BACKGROUND STUDY

2.1  Introduction  13

2.2  Potential Solar Energy in Malaysia  13

2.3  Obstacles of Solar Energy as Renewable Energy Source  17

2.4  Solar PV Panel  18

2.4.1  Monocrystalline  18

2.4.2  Polycrystalline  18

2.4.3  Amorphous Silicon or “Thin Film"  19

2.5  Categorized of Solar PV Power Plant  21

2.6  Malaysia Feed in Tariff (FiT)  21

2.7  The Key Features of the FiT  23

2.7.1  RE Technologies  23

2.7.2  Digressions Rates  23

2.7.3  Renewable Energy Power Purchase Agreement  23

2.7.3  Installed Capacity  23

2.7.5  Bonus FiT Rates  23

2.7.6  Commercial Operation Date  23

2.8  Hybrid Power System for Remote Areas  30

2.9  Economic Point of View  30

2.10  Summary  32
## CHAPTER 3  SOLAR PV POWER PLANT FRAMEWORK PERFORMING & ECONOMY ANALYSIS

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Introduction</td>
<td>33</td>
</tr>
<tr>
<td>3.2</td>
<td>Research Framework</td>
<td>33</td>
</tr>
<tr>
<td>3.3</td>
<td>Plant Performance Analysis</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>3.3.1 Analysis of the Solar PV Performance</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>3.3.2 PV Economic Analysis</td>
<td>38</td>
</tr>
<tr>
<td>3.4</td>
<td>Hybrid Analysis of PV + Battery + Generator Framework Model</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>3.3.1 Hybrid Power Economy Analysis</td>
<td>40</td>
</tr>
<tr>
<td>3.5</td>
<td>Constraint Analysis</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>3.5.1 Demand Balance</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>3.5.2 Energy Ratio</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>3.5.3 Reinvestment</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>3.5.4 Budget Constraint</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>3.5.5 Angle Limit</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>3.5.6 Capacity of PV Generation</td>
<td>45</td>
</tr>
<tr>
<td>3.6</td>
<td>Summary</td>
<td>46</td>
</tr>
</tbody>
</table>
CHAPTER 4 STUDY CASE OF 8MW SOLARPOWERPLANT AND HYBRIDPOWER SYSTEM

4.1 Introduction 47

4.2 8 MW Solar PV Power Plant 47
   4.2.1 Performance Degradation Factor 50
   4.2.2 Solar Renewable VS Conventional Power Plant 50

4.3 Hybrid System 54
   4.3.1 Perak Island and Jarak Island 55

4.4 Renewable Hybrid Power System 56

4.5 Energy Use at Perak Island and Jarak Island 60

4.6 Economy Analysis of Existing Technology 63

4.7 Summary 64

CHAPTER 5 RESULT AND DISCUSSIONS

5.1 Introduction 65

5.2 Deterministic Case Study 65

5.3 Economy Analysis of Hybrid Power Systems 73

5.4 Comparison with Existing Software 83

5.5 Summary 86
CHAPTER 6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion and Thesis Summary 87

6.2 Contribution of the Thesis 88

6.3 Future Work 89

REFERENCES 90

APPENDICES 95

A Malaysia Solar Irradiation Data 95

B Example of Hybrid Systems Propose for Island 115

C List of Publication 116
# LIST OF TABLE

<table>
<thead>
<tr>
<th>Table No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Total import for a coal and country involve</td>
<td>4</td>
</tr>
<tr>
<td>1.2</td>
<td>Data for PV for PV installations and installed</td>
<td>7</td>
</tr>
<tr>
<td>2.1</td>
<td>Advantages of the FiT</td>
<td>22</td>
</tr>
<tr>
<td>2.2</td>
<td>Malaysia target of RE capacity (MW) 2011 to 2030</td>
<td>24</td>
</tr>
<tr>
<td>2.3</td>
<td>FiT rates for Biogas</td>
<td>25</td>
</tr>
<tr>
<td>2.4</td>
<td>FiT rates for Small Hydro</td>
<td>25</td>
</tr>
<tr>
<td>2.5</td>
<td>FiT rates for Biomass</td>
<td>26</td>
</tr>
<tr>
<td>2.6</td>
<td>Continue from FiT rates for Biomass</td>
<td>27</td>
</tr>
<tr>
<td>2.7</td>
<td>FiT rates for Solar photovoltaic</td>
<td>27</td>
</tr>
<tr>
<td>2.8</td>
<td>Continue from FiT rates for Solar photovoltaic</td>
<td>28</td>
</tr>
<tr>
<td>2.9</td>
<td>RM/kWh Solar PV FiT tariff according to years effective</td>
<td>28</td>
</tr>
<tr>
<td>3.1</td>
<td>Angle impact constraint factor</td>
<td>45</td>
</tr>
<tr>
<td>4.1</td>
<td>Cost comparisons of solar PV and coal fired power plant.</td>
<td>53</td>
</tr>
<tr>
<td>4.2</td>
<td>Actual data of total energy use according to the list of equipment for both island</td>
<td>62</td>
</tr>
<tr>
<td>4.3</td>
<td>Example of energy eco system</td>
<td>62</td>
</tr>
<tr>
<td>4.4</td>
<td>Economy analysis of the technology for both islands</td>
<td>63</td>
</tr>
<tr>
<td>5.1</td>
<td>Optimize result for solar PV hybrid system generate by HOMER</td>
<td>84</td>
</tr>
<tr>
<td>5.2</td>
<td>Comparison result HOMER with the propose framework</td>
<td>85</td>
</tr>
</tbody>
</table>
### LIST OF FIGURE

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Total PV installed capacity from 1992 to 2012</td>
<td>2</td>
</tr>
<tr>
<td>1.2</td>
<td>The annual PV installed capacity from 1992 to 2012</td>
<td>3</td>
</tr>
<tr>
<td>1.3</td>
<td>Malaysia subsidize from 1997 to 2011</td>
<td>4</td>
</tr>
<tr>
<td>1.4</td>
<td>Diversity of energy in Malaysia to produce electricity</td>
<td>5</td>
</tr>
<tr>
<td>1.5</td>
<td>The installation target for renewable in Malaysia</td>
<td>8</td>
</tr>
<tr>
<td>2.1:</td>
<td>Daily average solar radiation in Malaysia MJ/m²/day</td>
<td>14</td>
</tr>
<tr>
<td>2.2</td>
<td>Average world solar radiation kWh/m²/year</td>
<td>15</td>
</tr>
<tr>
<td>2.3</td>
<td>Solar irradiation data in region in Malaysia facing true south kWh/m²/year</td>
<td>15</td>
</tr>
<tr>
<td>2.4</td>
<td>Monthly solar energy data performance for energy PV region in Malaysia</td>
<td>16</td>
</tr>
<tr>
<td>2.5</td>
<td>Solar energy data for region in Malaysia facing true south kWh/m²/year</td>
<td>16</td>
</tr>
<tr>
<td>2.6</td>
<td>Different type, shapes and technology of PV panel</td>
<td>20</td>
</tr>
<tr>
<td>2.7</td>
<td>Example of components involve in solar PV power generation</td>
<td>20</td>
</tr>
<tr>
<td>2.8</td>
<td>Movement of solar FiT digression value.</td>
<td>29</td>
</tr>
<tr>
<td>3.1</td>
<td>Research framework</td>
<td>34</td>
</tr>
<tr>
<td>4.1</td>
<td>8 MW Pajam solar PV power plant under Cypark Resources Berhad</td>
<td>47</td>
</tr>
<tr>
<td>4.2</td>
<td>Revenue generating through FiT contract</td>
<td>48</td>
</tr>
<tr>
<td>4.3</td>
<td>Profit generate over life of FiT contract</td>
<td>49</td>
</tr>
<tr>
<td>4.4</td>
<td>Profit percentage of generate performance through FiT contract</td>
<td>50</td>
</tr>
<tr>
<td>4.5</td>
<td>Coal power plant (JanaKuasaManjung)</td>
<td>51</td>
</tr>
</tbody>
</table>
4.6 Costing operation involved in JanaManjung Coal fired Power Plant
4.7 View of Perak and Jarak Island
4.8 Hybrid power system
4.9 Block Function of the system
4.10 Flow chart of the hybrid system operation
4.11 Usage of electric energy at both islands
4.12 Generator and solar PV energy generating
4.13 Hybrid power system
5.1 Overall performance for 8 MW solar PV power plant
5.2 Pajam solar PV power plant performance
5.3 Temperature effect for 8 MW Pajam solar PV power plant
5.4 Revenue_{i}^{pv}$ in RM of 8 MW Pajamsolar PV power plant
5.5 Total T\textsuperscript{PV}{P}_{i} generation and performanceof the Pajam power plant
5.6 Illustration of return investment in million (RM) for 8 MW in 21 years
5.7 Systems performance correction at 75% with manufacture standard digression
5.8 Systems performance correction at 75% with constraint digression
5.9 LCOE thorough the year of period feed in tariff
5.10 Cost of installation for each technology
5.11 Cost of operation maintenance(OM) for generator without energy storage
5.12 Cost of operation & maintenance (OM) for generator with added energy storage (battery)
5.13 Different of total cost of three type of installation
5.14 Total cost of hybrid systems with different of percentage solar PV installation
<table>
<thead>
<tr>
<th>Section</th>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.15</td>
<td>Frequent of minor service for 21 years</td>
<td>78</td>
</tr>
<tr>
<td>5.16</td>
<td>Frequent of major service for 21 years</td>
<td>78</td>
</tr>
<tr>
<td>5.17</td>
<td>The cost of diesel</td>
<td>79</td>
</tr>
<tr>
<td>5.18</td>
<td>The cost of operation maintenance</td>
<td>80</td>
</tr>
<tr>
<td>5.19</td>
<td>Revenue</td>
<td>81</td>
</tr>
<tr>
<td>5.20</td>
<td>Total money of saving</td>
<td>82</td>
</tr>
<tr>
<td>5.21</td>
<td>Performance of the systems</td>
<td>82</td>
</tr>
<tr>
<td>5.22</td>
<td>Hybrid system setup in HOMER</td>
<td>83</td>
</tr>
</tbody>
</table>
LIST OF SYMBOLS

\( i \)  
Zone

\( k \)  
Year

\( M \)  
Year before

\( \eta \)  
Solar PV power plant efficiency [%]

\( \eta^\text{PVref} \)  
PV module efficiency reference [%]

\( \eta' \)  
Effective solar PV power plant efficiency [%]

\( G_{\text{stc}} \)  
Global sun irradiation [1000W/m²]

\( A_{\text{eff}} \)  
Area of effective [m²]

\( \theta_{\text{eff}} \)  
Temperature effective

\( f_\delta_i \)  
Factor of angle displacement

\( PP_{\text{sys}}^{\text{PV}} \)  
Systems performance

\( \text{Avh} G_{\text{stc}} \)  
Average hour of effective Sun radiation

\( f DG^{\text{PV}} \)  
Digression of PV performance

\( f stcDG^{\text{PV}} \)  
Standard digression of PV performance

\( f \text{DSys} \)  
Total derating factor of the system [decimal]

\( fDVdrp \)  
Derating factor for voltage drop [decimal]

\( fD_{\text{dirt}} \)  
Efficiency for dirt at PV panel [decimal]

\( f DG^{\text{PVinv}} \)  
Inverter digression fraction

\( PP_i^{\text{PV}} \)  
Peak power PV generation [W]

\( PG^{\text{PVe}} \)  
PV effective power generating [W]

\( PG_{i}^{\text{PVe}} \)  
Yearly PV effective power generating [W]

\( GE_{\text{sys}}^{\text{PV}} \)  
Total PV energy generate for the systems [W]

\( AppE_{\text{sys}}^{\text{PV}} \)  
Approximate energy of PV systems.

\( LP^{\text{PV}} \)  
PV performance losses

\( Mx_i^{\text{PV}} \)  
Maximum PV output [W]

\( Tc_{i}^{\text{PV}} \)  
Operational cell temperature

\( Tamb_i^{\text{PV}} \)  
Ambiance temperature
\[ Revenue_{i}^{pv} \] Revenue of PV power [RM]
\[ FIT_{k}^{eff} \] Affective feed in tariff [RM]
\[ FIT_{k}^{Yb} \] Year precedent feed in tariff value [RM]
\[ FIT_{k}^{DG\%} \] FIT digression value in [RM]
\[ TP_{i}^{pv} \] Total Profit of PV power [RM]
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRBInc</td>
<td>Power required balance</td>
</tr>
<tr>
<td>PGen</td>
<td>Power of generator</td>
</tr>
<tr>
<td>Pdct</td>
<td>Policy Discount</td>
</tr>
<tr>
<td>RM</td>
<td>Ringgit Malaysia (Currency)</td>
</tr>
<tr>
<td>TCST</td>
<td>Total cost</td>
</tr>
<tr>
<td>CEQ</td>
<td>Equipment cost</td>
</tr>
<tr>
<td>CSHP</td>
<td>Shipment cost</td>
</tr>
<tr>
<td>CLB</td>
<td>Labor cost</td>
</tr>
<tr>
<td>CINV</td>
<td>New investment cost</td>
</tr>
<tr>
<td>COM</td>
<td>Operation maintenance cost</td>
</tr>
<tr>
<td>TCGenOM</td>
<td>Total generator operation maintenance cost</td>
</tr>
<tr>
<td>ACFL</td>
<td>Actual fuel cost</td>
</tr>
<tr>
<td>CmrOM</td>
<td>Minor operation maintenance cost</td>
</tr>
<tr>
<td>CmjOM</td>
<td>Major operational maintenance cost</td>
</tr>
<tr>
<td>CovhOM</td>
<td>Over hall maintenance cost</td>
</tr>
<tr>
<td>CGenRpLc</td>
<td>Generator replaces cost</td>
</tr>
<tr>
<td>TMU</td>
<td>Time utilization of generator</td>
</tr>
<tr>
<td>CFLr</td>
<td>Fuel consummation at required load</td>
</tr>
<tr>
<td>EFTYr</td>
<td>Year of utilizations</td>
</tr>
<tr>
<td>CFTr</td>
<td>Cost per liter</td>
</tr>
<tr>
<td>NmrFrq250H</td>
<td>Number of frequent minor service at 250h, 500h, and 750h</td>
</tr>
<tr>
<td>CmrM</td>
<td>Cost of minor operation maintenance</td>
</tr>
<tr>
<td>NmjFrq1000H</td>
<td>Number of frequent major service at 1000h</td>
</tr>
<tr>
<td>CmjM</td>
<td>Cost of major operation maintenance</td>
</tr>
<tr>
<td>GenPC</td>
<td>Generator price</td>
</tr>
<tr>
<td>NovhFreq10 000H</td>
<td>Number of frequent over hall service at 10 000h</td>
</tr>
<tr>
<td>TCPVOM</td>
<td>Total cost of PV operational maintenance</td>
</tr>
<tr>
<td>CBttOM</td>
<td>Cost of battery operational maintenance</td>
</tr>
</tbody>
</table>
CPVRom  Cost of PV maintenance
TCHYBsys Total cost hybrid systems
T_{profit} Total profit
T_{cost} Total cost
TRVN Total revenue
PV_{RVN} PV revenue
GEN_{RVN} Generator revenue
HybridFIT Hybrid feed in tariff
HybridEsys Total power hybrid energy systems
FiT Feed in tariff
PGen Generator generate power
PrC/Kw Price/Kw
TC_{INT} Total cost of installation
PPVsys PV power generate
PGen Generator power generate
Pbatt Power battery
Pload Load power
xPPVsys Percentage of PV systems installation
yPGen Percentage of generator systems installation
zPbatt Percentage of battery systems installation
Pload Total load power install
PTsysYearsSetup Total of power performance of the systems at year setup
PTsysYearsActual Total power performance systems at Actual year
T_{cost} Total cost
Tbudget Total budget
Nowadays, the increasing of using renewable energy (RE) as an alternative for generating power has brought an attention to the most countries. Current power generations, in which can be called conventional ones, are using the fossil fuel such as coal, gas and oil in operating the power plant. Therefore, indirectly it has faced the problem of uncertainty in fossil fuel price, resources availability, carbon emission and energy supply to remote areas. To date, Malaysia has spent more than billion in costing to acquire the fossil fuel to generate the power plant. In that reasons, the introduction of RE for energy supply is vital. Since the solar energy has become prominent in energy supply nowadays, the potential for large scale power plant is high, whereby, so far one of 8 MW solar PV power plant has been developed in Pajam. To develop a large scale solar energy is more expensive when compared to conventional ones. In economic analysis point of view, the proper framework that suite with Malaysia perspective such as environment, geographical, climate and suitable technique as a parameters needs to be carried determine first, so that the nearest prediction of return of investment can be anticipated. The analysis is presented by closer look at the plant performances and profits generated with consider the possible constraint factors that enforce by the environment factor and the technology. The case study is conducted to show the analysis assessment for large scale solar PV power plant up to 8 MW and the result will indicate the potential of solar being use as renewable energy to generate electricity and making profit. Meanwhile, the problems of supplying electricity to remote areas due to the geographical condition are studied by analyzing an economic analysis of hybrid energy supplies. An exploitation of solar energy with energy storage (battery) and diesel generator as hybrid energy sources to remote areas is proposed by come up an economic analysis of the hybrid energy system. The case studies at the remote islands (Perak and Jarak islands) are carried out. The outcome of the study case will show that with the correct sizing and design, money can be saving and dependency to diesel generator can be reduced.
ABSTRAK

REFERENCES


&y=45&s=1987


[23] Cours de QUALIPV – Formation de générateur PV raccordé 2008 at Universitie Sophia Anti Polis Nice.France


[29] Ahmad, M. Hamdan and Dilshan, Ramez Ossen and Chia, Sok Ling (2004)-“Impact Of Solar Radiation On High-Rise Built Form In Tropical Climate”. In: The 5th International Seminar on Sustainable Environment Architecture, 10-12 Dec. 2004, Sapphire Hall, GoodHope Hotel, Johor, Malaysia.


[38] Info of electric power consumption (kWh) in Malaysia available at: http://www.tradingeconomics.com/malaysia/electric-power-consumption-kwh-wb-data.html


[40] Information about statistic for energy balance, energy data analysis, energy prices by Malaysia Energy Commission available at:http://meih.st.gov.my/statistics


APPENDIX C1


