TECHNO-ECONOMIC COMPARISON BETWEEN CONCENTRATED SOLAR THERMAL POWER AND SOLAR PV WITH BATTERY ENERGY STORAGE TECHNOLOGY

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DECLARATION

I declare that this is my own work, and this dissertation 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.

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Abstract

Renewable energy sources are becoming increasingly important in meeting global energy demands and reducing greenhouse gas emissions. Concentrated Solar Power (CSP) of Parabolic trough technology and Solar Photovoltaic (PV) with Battery Energy Storage Systems (BESS) are two promising technologies that can provide renewable energy to the grid.

This study aims to determine which technology is more technically and economically viable for medium and large-scale power generation and storage. The dissertation includes seven chapters with a detailed literature review and a discussion of analysis of the costs, efficiencies, and overall performance of these two technologies. Further, the study analyzes the feasibility of each technology based on factors such as levelized cost of electricity (LCOE).

The analysis is carried out for a 10 MW CSP plant with 40 MWh molten salt storage and a 10 MW + 40 MWh PV+BESS system, both located in a high solar irradiance region. The results indicate that while CSP has a higher plant factor and LCOE of 26.96 $cents/kWh, PV+BESS has higher dispatchability and lower upfront capital cost with low LCOE of 23.27 $cents/kWh. A sensitivity analysis of both technologies was also conducted to examine the LCOE variation with respect to the cost variation of major CAPEX category, solar multiple, DC to AC ratio, storage capacity. O&M cost analysis is carried out to compare the overheads. From the comparison between both technologies at different plants and storage capacities it is identified CSP is a viable solution than PV+ BESS for above 20 MW of 4-hour storge capacity when only dispatchability is considered. The comparison between the LCOE with the storage and the capacity of each technology proves that CSP systems are particularly well-suited for capacities above 50 MW, where they can take advantage of economies of scale and achieve lower LCOE.

Further a market analysis was also conducted for a PPA price ascertainment. In the sensitivity analysis of the PPA prices it is found that PPA prices range from 50 rupees to Rs.105/kWh, taking as 1USD = Rs.360.00 a positive NPV is from Rs.55/kWh for the CSP system and NPV is positive for Rs.50/kWh for PV+ BESS.

Key words – Solar PV plus Battery Energy Storage Systems, Concentrated solar power, Levelized cost of electricity, PPA price, financial analysis, Parabolic trough, System advisory model, Thermal storage, Module efficiency, capacity factor.

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TABLE OF CONTENTS

Abstract ii

Acknowledgements iii

List of Figures vii

List of Tables ix

List of Abbreviations xi

1. Introduction 1

2. Literature Review 2

2.1 Technology description 2

2.1.1 Concentrated solar thermal power plant 2

2.1.2 Solar PV with battery energy storage 5

2.2 Location selection 8

2.3 Software used for the techno economic analysis 10

2.3.1 System Advisory Model 10

2.3.2 Meteonorm 11

2.3.3 PV Syst 11

2.4 Importance of energy storage to Sri Lanka 11

2.5 Resource assessment for CSP and PV + BESS 12

2.5.1 General conditions 13

2.5.2 Aerosol variation 18

2.5.3 Plant capacity 19

2.5.4 Power evacuation 20

3 CS plant system modeling and methodology 21

3.1 CSP plant component selection 21

3.1.1 Parabolic trough collector (PTC) 21

3.1.2 Receiver model 22

3.1.3 CSP plant storage technology 24

3.1.4 Power block of the CSP plant 26

3.2 Sizing of CSP plant 29

3.2.1 Solar multiple 29

3.2.2 Land usage 30

4 PV + BESS plant system modeling and methodology 31

4.1 Solar module selection 31

4.1.1 P-Type vs N-Type 34

4.1.2 Mono-facial or bifacial 34
4.2 DC:AC ratio 35
4.3 Mounting structures 36
4.4 Proposed structure for a fixed tilted system 36
4.5 Inverter selection 37
4.6 Battery storage system 38
4.6.1 Specification of Battery Cell 39
5 Results 42
5.1 CSP plant with thermal storage modelling results 42
5.1.1 Production data results 42
5.1.2 Parasitic losses 48
5.1.3 Performance degradation 48
5.1.4 Cost assessment of CSP with thermal storage 49
5.2 Solar PV plant with BESS modeling results 50
5.2.1 Plant factor assessment 51
5.2.2 Production assesment 53
5.2.3 Energy losses from the system 55
5.2.4 Battery parameter assessment 56
5.2.5 Cost assessment of PV + BESS system 57
6 Discussion And Analysis 60
6.1 CSP with thermal storage plant analysis 64
6.1.1 LCOE variation with the CSP system capacity 65
6.1.2 LCOE variation with respect to the CSP solar multiple 66
6.1.3 LCOE variation with respect to the storage 67
6.2 PV with BESS plant analysis 68
6.2.1 LCOE variation with the PV and BESS capacity 70
6.2.2 LCOE variation with respect to the change in PV module price 71
6.3 LCOE comparison 71
6.3.1 LCOE variation with respect DC:AC ratio 72
6.4 O&M cost analysis 73
6.4.1 CSP O&M cost analysis 73
6.4.2 PV + BESS O&M cost analysis 74
6.4.3 Comparison 75
6.5 PPA price ascertainment 76
6.5.1 CSP with thermal storage PPA price ascertainment 77

4.1.1 PV + BESS PPA price ascertainment 78
4.1.2 PPA price sensitivity analysis 79
7 Conclusion 83
References 84
Appendix A: Cost of the CSP System in SAM 87
Appendix B: Cost of the PV + BESS System in SAM 88
Appendix C – Data sheet – Tiger Neo N-Type 78HL4-(V) 595-615 Watt 89
Appendix D – Data Sheet – SMA String Inverters 90
Appendix E – AC Capacity Factors Under Different Design Options 93
Appendix F – Loan Interest Rate Forecast 97

List of Figures

Figure 2.1 Schematic diagram of a parabolic trough CSP plant 4
Figure 2.2 Components of a DC-coupled PV-plus-battery system 6
Figure 2.3 Block diagram of a DC coupled PV plus BES system. 7
Figure 2.4 Earmarked location for the tecno-economic analysis. 10
Figure 2.5 Sri Lanka load curve 12
Figure 2.6 Method for the design approach 13
Figure 2.7 Monthly Variation in Global Horizontal Irradiation 14
Figure 2.8 Temperature variation within the year 15
Figure 2.9 Average TSI and DNI data in Gonnoruwa II weather station 17
Figure 2.10 Aerosol Optical Depth (AOD) Seasonal patterns for Sri Lanka and the Maldives. Ref: [19] 19
Figure 3.1 Image of a SolarGenix SGX-1 Heliostat 22
Figure 3.2 Schott PTR80 receiver 23
Figure 3.3 Condenser model pressure variance in accordance with the temperature 28
Figure 4.1 AC Power Output under Different DC:AC Ratios 35
Figure 4.2 Incremental Electricity Generation under Different DC:AC Ratios 36
Figure 4.3 Tilt angle optimization 37
Figure 4.4 Orientation of modules 37
Figure 4.5 ESS infrastructure arrangement 39
Figure 4.6 Battery degradation relevant to the DoD level 41
Figure 4.7 Effective capacity of BESS with number of cycles 41
Figure 5.1 Monthly generation graph of CSP 44
Figure 5.2 Field collector DNI data 45
Figure 5.3 System power generation 46
Figure 5.4 TES charge, discharge, and electricity to grid 47
Figure 5.5 System power generated vs PC input thermal power 47
Figure 5.6 Cost distribution of different parts of the proposed CSP plant 50
Figure 5.7 Estimated AC capacity factors under different options. 52
Figure 5.8 Solar PV + BESS plant energy generation 53
Figure 5.9 Energy to the grid from battery 54
Figure 5.10 Detailed summary of total annual generation and losses specifically 55
Figure 5.11 Total system losses 56
Figure 5.12 Cycles specified for DOP of the battery 57

Figure 5.13 Cost distribution of different parts of the proposed PV+BESS system.. 59
Figure 6.1 Interest rate forecast.......... 64
Figure 6.2 Levelized cost variation with the capacity.......... 66
Figure 6.3 Levelized cost of electricity variation with solar multiple. 67
Figure 6.4 LCOE vs the Hours of storage.......... 68
Figure 6.5 PV + BESS Plant LCOE in Various Capacities 71
Figure 6.6 LCOE variation with change in PV module price.......... 71
Figure 6.7 LCOE variation with the technology and the capacity.......... 72
Figure 6.8 LCOE variation with respect to DC:AC ratio 73
Figure 6.9 Cost of various expenses of CSP.......... 74
Figure 6.10 PV + BESS O&M Costs.......... 75
Figure 6.11 Comparison of O&M expenses 76
Figure 6.12 IRR vs PPA price.......... 77
Figure 6.13 NPV vs PPA price 78
Figure 6.14 IRR vs PPA price of PV + BESS system 79
Figure 6.15 NPV vs PPA price of the PV + BESS system.......... 79
Figure 6.16 NPV vs PPA price of CSP plant.......... 80
Figure 6.17 IRR vs PPA price of CSP plant 81
Figure 6.18 NPV vs PPA price for PV + BESS.......... 81
Figure 6.19 IRR vs PPA price for PV + BESS 82

List of Tables

Table 2.1 CSP technology specifications and use in the world 3
Table 2.2 Yearly sums of direct normal irradiance DNI (kWh/m2) for the SOLEMI data points. 9
Table 2.3 Yearly sums of global horizontal Irradiance GHI (kWh/m²) for the SOLEMI data points. 9
Table 2.4 Site preliminary details 10
Table 2.5 Comparison of Actual and Simulated Electricity Generation Gonnoruwa I 15
Table 2.6 Comparison of Actual and Simulated Electricity Generation Gonnoruwa II 16
Table 2.7 Selecting the Best Solar Resource Data Source.. 17
Table 2.8 Gonnoruwa II plant information 18
Table 2.9 Selected resource parameters for the analysis.. 18
Table 2.10 Existing power plant capacities in the area 20
Table 3.1 Heliostat configuration... 22
Table 3.2 Selected receiver specifications 23
Table 3.3 Selected thermal storage details.. 25
Table 3.4 SAM parameters for the simulation 25
Table 3.5 Power block input parameters to the SAM software 27
Table 3.6 Selected electric generator specifications 28
Table 3.7 Other options for turbine models and capacities....................................... 29
Table 4.1 Solar PV Module Models Considered in the Study 33
Table 4.2 Incremental Energy Yield of Bifacial Module.. 35
Table 4.3 Inverter models considered in the study 38
Table 4.4 Scope of items in Jinko-Solar ESS 39
Table 4.5 Lithium-ion phosphate (LFP) cell specs 40
Table 5.1 Input parameters of the CSP plant 42
Table 5.2 Production output parameters of the SAM software................................. 43
Table 5.3 CSP monthly generation data.. 43
Table 5.4 Parasitic losses of the CSP plant 48
Table 5.5 CSP plant costs used for SAM inputs 49
Table 5.6 Input parameters to the financial model.. 51
Table 5.7 Estimated AC capacity factors under different options. 52

Table 5.8 Solar PV + BESS plant costs 58
Table 6.1 General parameters for the financial model.. 62
Table 6.2 Parameters for financial model 65
Table 6.3 CSP plant input parameters for the financial model 65
Table 6.4 LCOE value at nominal and real scenarios.. 65
Table 6.5 Capacity, storage size and land requirement.. 68
Table 6.6 Output parameters from the SAM.. 69
Table 6.7 LCOE of PV and BESS 69
Table 6.8 Input parameters to the financial model.. 70
Table 6.9 LCOE variation to different DC:AC ratios.. 72
Table 6.10 Interest arrangement of CSP system 77
Table 6.11 Interest arrangement of PV+BESS 78

List of Abbreviations

Abbreviation	Description
AC	Alternating Current
DC	Direct Current
CEB	Ceylon Electricity Board
CAPEX	Capital Expenditure
CSTP	Concentrated Solar Thermal Power
CLFR	Compact Linear Fresnel Reflector
CWEC	Canadian Weather for Energy Calculation
CEA	Central Environmental Authority
CSP	Concentrated Solar Power
DOD	Depth of Discharge
DNI	Direct Normal Irradiation
DSG	Direct Steam Generation
ES	Energy Storage
FIT	Feed in Tariff
HCE	Heat Collection Element
HFC	Heliostat Field Collector
HTF	Heat Transfer Fluid
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
ISCC	Integrated Solar Combined Cycle
IWEC	International Weather for Energy Calculation
kW	Kilo Watts
LFP	Lithium-Iron Phosphate
Li-ion	Lithium-Ion Metal Oxide
LCOE	Levelized Cost of Energy
LCOS	Levelized Cost of Storage
LFR	Linear Fresnel Reflector
MW	Mega Watts
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
NSRDB	National Solar Resource Data Base

O&M	Operation and Maintenance
PPA	Power Purchase Agreement
PDC	Parabolic Dish Collector
PTC	Parabolic Trough Collector
PV	Photovoltaics
RE	Renewable Energy
SLSEA	Sri Lanka Sustainable Energy Authority
SAM	System Advisor Model
SPT	Solar Power Tower
SOC	State of Charge
SCA	Solar Collector Assembly
SM	Solar Multiple
SWERA	Solar Wind Energy Resource Assessment
TES	Thermal Energy Storage
VRE	Variable Renewable Energy