Contents

CERTIFICATE iii

DECLARATION BY THE CANDIDATE v

COPYRIGHT TRANSFER CERTIFICATE vii

ACKNOWLEDGMENT ix

ABSTRACT xxvii

Chapter 1 **Introduction and Background** 1

1.1 Introduction 1

1.2 Renewable Energy Resources 2

1.2.1 Classification of Renewable Energy Resources 2

1.2.2 History of Renewable Energy Resources 3

1.3 Solar Energy 6

1.3.1 Solar Energy Utilization 6

1.3.2 Available Solar Radiation 7

1.3.3 Extraterrestrial Solar Radiation 8

1.3.4 Terrestrial Solar Radiation 9

1.4 Elements of Solar Geometry 10

1.5 Basics of Solar Collector Technology 14

1.5.1 Solar Concentrating Technology 15

1.5.1.1 Line Concentrating 18
1.5.1.2 Point Concentrating 19
1.6 Parabolic Trough Technology 19
1.6.1 Solar Receiver Tube 20
1.6.2 Heat Transfer Fluid 21
1.6.3 Structure, Mirrors and Glass Cover 22
1.7 Analysis of Parabolic Trough Collector 24
1.7.1 Basic Terminology and Derivation 24
1.7.2 Design and Construction Details 31
1.8 Solar Energy Storage 33
1.8.1 Energy Storage Methods 34
1.8.1.1 Mechanical Energy Storage 34
1.8.1.2 Electrical Energy Storage 35
1.8.1.3 Thermo Chemical Energy Storage 35
1.8.1.4 Thermal Energy Storage 36
1.9 Solar Collector Applications 37

Chapter 2 **Review Analysis** **39**
2.1 Introduction 39
2.2 Parabolic Dish Type Solar Collector System 39
2.2.1 Parabolic Dish Collector for Power Generation 40
2.2.2 Parabolic Dish Collector for Cooking Purposes 41
2.3 Parabolic Trough type solar collector system 46
2.3.1 Solar Receiver Systems 49
2.4 Findings of the Review 54
2.5 Research Gap 54
2.6 Problem Statement 55
2.7 Objective of the Study 55
2.8 Scope of the Study 56
2.9 Methodology of Study 56

Chapter 3 **Experimentation** **59**

3.1 Introduction 59

3.2 Mathematical Analysis of solar collectors 59

3.2.1 Assumptions 59

3.3 Model of the Present PTC System 67

3.3.1 Total Length of the Helical Coil (L): 67

3.3.2 Heat Loss Equation Model: 68

3.3.3 Conversion Efficiency Helical Coil Receiver (η_c): 69

3.4 Experimental Analysis 69

3.4.1 Description of Receiver System 72

3.5 Instrumentation 72

3.5.1 Measurement of Experimental Parameters 74

3.5.2 Temperature Measurement 79

3.5.3 Measurement of Environmental parameters 80

3.6 Experimental Observations 80

3.7 Data Reduction 82

3.7.1 Solar Irradiation Absorptions 82

3.7.2 Useful Energy Gain 82

3.7.3 Calculation of Nusselt Number(Nu) 85

3.7.4 Calculation of Thermal Efficiency(η) 86

3.7.5 Pressure Drop Calculation 86

3.7.6 Mass Flow Rate Calculation ($\dot{m}$) 86

3.8 Experimental Results 87

3.9 Uncertainty Analysis 91

Chapter 4 **Modeling of a Parabolic Dish and Trough solar Concentrators** **93**

4.1 Modeling of a Parabolic Trough solar Concentrator 93

4.1.1 One Dimensional Energy Balance Model 94

4.1.2 Convection Heat Transfer between the HTF and the Absorber 95

4.1.3 Nusselt Number Calculation 98

4.1.4 Conduction Heat Transfer through the Absorber Wall (Q_4) 100
4.1.5 Heat Transfer from the Absorber to the 1^{st} Glass Cover 100
4.1.6 Convection Heat Transfer (Q_6) 101
4.1.7 Radiation Heat Transfer (Q_7) 102
4.1.8 Heat Transfer from the 1st Glass Cover to 2nd Glass 102
4.1.8.1 Convection Heat Transfer (Q_9) 102
4.1.8.2 Radiation Heat Transfer (Q_{10}) 105
4.1.9 Heat Transfer from the 2nd Glass Cover to Atmosphere 105
4.1.9.1 Convection Heat Transfer (Q_{12}) 105
4.1.9.2 Free Convection (no wind case) 106
4.1.9.3 Force Convection (wind case) 107
4.1.9.4 Radiation Heat Transfer (Q_{13}) 108
4.1.10 Heat Loss through Supporting Rod and Bracket 108
4.1.11 Optical Properties 109
4.1.12 Solar Irradiation Absorption in the 2nd Glass Cover (Q_1) 110
4.1.13 Solar Irradiation Absorption In the 1st Glass Cover (Q_2) 111
4.1.14 Solar Irradiation Absorption in the Absorber (Q_3) 111
4.1.15 Exegetic Modeling 112
4.1.16 Pressure Drop Across the Helical Coil Solar Cavity Receiver 114
4.2 Modeling of Dish Type Solar Concentrator 115
4.2.1 Heat Transfer Equations 115
4.2.2 Loss Investigation 116
4.2.2.1 Side Loss: 116
4.2.2.2 Bottom Loss: 118
4.2.2.3 Top Loss: 119
4.2.2.4 Total Loss: 120
4.2.3 Performance Index (PI) 120
4.2.4 Efficiency of Dish type collector (η) 121
4.3 Model Validation 121

Chapter 5 **Results and Discussion** **127**

5.1 Parabolic Trough Type Solar Collector 127

5.1.1 Environmental Parameters 128

5.1.2 Conversion Efficiency 131

5.1.3 Effect of Vacuum Pressure and Wind Speed 132

5.2 Dimensionless Numbers for Internal Flow through Helical Coil Solar Cavity Receiver 135

5.3 Temperature and Heat Flux Distribution over Helical Coil Receiver System 136

5.3.1 Comparison of Horizontal Tube Receiver and Helical Coil Tube Receiver 142

5.3.2 Conversion Efficiency of Parabolic Trough Concentrator 143

5.3.3 Effect of Pressure at Annular Space on the Performance of Helical Coil Receiver 146

5.4 Parabolic Dish type Solar Collector 149

5.4.1 Environmental Parameters 149

5.4.2 Heat Loss Analysis (side loss, bottom loss, and top loss) 151

5.5 New Approach to Measure the Performance of Dish Type Solar Collector System 155

5.5.1 Performance Index and Efficiency Analysis 155

Chapter 6 **Conclusions and Scope for Future Work** **157**

6.1 Conclusions 157

6.2 Scope for Future Work 160

References **161**

Publications **179**

Chapter A Solar Radiation Data **183**

Chapter B Simple Calculations Using EES Software **211**