



# **Parametric Study of a Novel Low Temperature Cycle for Electricity and Fresh Water Production**

By

**Eng. Karim Ehab Ahmed Hassan Hussain**

A Thesis Submitted to the Faculty of  
Engineering at Cairo University in Partial  
Fulfillment of the Requirements for the Degree of  
**MASTER OF SCIENCE**

In

**Mechanical Power Engineering**

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY**

**GIZA, EGYPT**

**2017**



# **Parametric Study of a Novel Low Temperature Cycle for Electricity and Fresh Water Production**

By

**Eng. Karim Ehab Ahmed Hassan Hussain**

A Thesis Submitted to the Faculty of  
Engineering at Cairo University in Partial  
Fulfillment of the Requirements for the Degree of  
**MASTER OF SCIENCE**

In

**Mechanical Power Engineering**

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY**

**GIZA, EGYPT**

**2017**



# **Parametric Study of a Novel Low Temperature Cycle for Electricity and Fresh Water Production**

By

**Eng. Karim Ehab Ahmed Hassan Hussain**

A Thesis Submitted to the Faculty of  
Engineering at Cairo University in Partial  
Fulfillment of the Requirements for the Degree of

**MASTER OF SCIENCE**

In

**Mechanical Power Engineering**

Under Supervision of

**Prof. Dr. Amin Mohamed Mobarak**

Mechanical Power Engineering Department  
Faculty of Engineering  
Cairo University

**Dr. Taher Mohamed Aboudeif**

Mechanical Power Engineering Department  
Faculty of Engineering  
Cairo University

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY**

**GIZA, EGYPT**

**2017**



# **Parametric Study of a Novel Low Temperature Cycle for Electricity and Fresh Water Production**

By

**Eng. Karim Ehab Ahmed Hassan Hussain**

A Thesis Submitted to the Faculty of  
Engineering at Cairo University in Partial  
Fulfillment of the Requirements for the Degree of  
**MASTER OF SCIENCE**

In

**Mechanical Power Engineering**

Approved by the Examining Committee:

**Prof. Dr. Amin Mohamed Mobarak**

**Thesis Main Advisor**

Professor of Mechanical Power Engineering, Faculty of Engineering, Cairo University.

**Prof. Dr. Zeinab Saleh Safar**

**Internal Examiner**

Professor of Mechanical Power Engineering, Faculty of Engineering, Cairo University.

**Prof. Dr. Mahmoud Abdelfattah ElKadi**

**External Examiner**

Professor of Mechanical Power Engineering, Faculty of Engineering, Al-Azhar University.

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY**

**GIZA, EGYPT**

**2017**





## Personal information

Engineer	<b>Karim Ehab Ahmed</b>		
Address	112 / Sudan St. Mohandeseen, Giza, (Egypt)		
Telephone	+20-237606088	Mobile	+20-1141108577
E-mail	karimehab@live.com	/	karimehab_1@hotmail.com
Nationality	Egyptian		
Date of birth	06 March 1987		
Gender	Male		
Marital status	Married		
Military status	Accomplished (2012)		



## Other Information

Registration Date	1 / 10 / 2012
Awarding Date	/ / 2017
Degree	Master of Science
Department	Mechanical Power Engineering
Main Supervisor	Prof. Dr.Amin Mohamed Mobarak
Supervisor	Dr. Taher Mohamed Aboudeif
Examiners	Prof. Dr. Amin Mohamed Mobarak Prof. Dr. Zeinab Saleh Safar Prof. Dr. Mahmoud Abdelfattah ElKadi Mechanical Power Engineering, Faculty of Engineering, Al-Azhar University.
Title of Thesis	Parametric Study of a Novel Low Temperature Cycle for Electricity and Fresh Water Production
Key Words	Modeling and Simulation, MSF, Parametric Design, Performance Optimization, Turbo-vapor Compressor, LP Steam Turbine.
Summary	Working on desalination and energy production is needed. And the best approach is the one which can produce both in parallel. The previous work was "A Novel Combined Low Temperature Cycle for Electricity and Fresh Water Production" Professor Amin Mobarak. Modeling and Simulation was conducted. The study also shows that changing the path of the distillate leaving the MSF plant may be useful. And finally plant optimizing is conducted which shows the best operating conditions for each environmental condition.



# Acknowledgments

I would like to thank Prof. Amin Mobarak. He not only did suggest and provide the material, but also supervised the work step by step. I am also indebted to Dr. Taher Mohamed who lent me his expertise and encouragement.

I would also Like to thank the system founders at the British University in Egypt (BUE) for allowing the teaching staff to have a free day per week to work on their research studies.

Special thanks to my parents and my wife for supporting me throughout the work and every single day.



# Table of Contents

<b>ACKNOWLEDGMENTS .....</b>	<b>I</b>
<b>LIST OF FIGURES.....</b>	<b>VII</b>
<b>NOMENCLATURE .....</b>	<b>XIV</b>
<b>ABSTRACT.....</b>	<b>XVII</b>
<b>CHAPTER 1 INTRODUCTION AND MOTIVATION.....</b>	<b>1</b>
<b>1.1 GENERAL .....</b>	<b>1</b>
1.1.1 DESCRIPTION OF THE NOVEL PLANT:	1
1.1.2 THESIS OUTLINE	2
<b>1.2 WATER DESALINATION.....</b>	<b>3</b>
1.2.1 POPULATION GROWTH PROBLEMS	3
1.2.1 FRESH WATER SOURCES	6
1.2.2 WATER DESALINATION NECESSITY	8
1.2.3 CLASSIFICATION OF DESALINATION TECHNOLOGIES	9
1.2.4 MARKET SHARE ACCORDING TO DESALINATION TECHNIQUE	10
1.2.5 CONCLUSION	11
1.2.6 SCOPE OF THE PRESENT WORK	11
<b>CHAPTER 2 LITERATURE OF MSF PLANTS MODELING.....</b>	<b>15</b>
<b>2.1 MULTISTAGE FLASH DESALINATION PROCESSES.....</b>	<b>15</b>
2.1.1 ONCE THROUGH MSF PROCESS	15
2.1.2 BRINE CIRCULATION MSF PROCESS	16
2.1.3 COMPARISON BETWEEN MSF PROCESSES	18
2.1.4 FLASHING STAGE DESCRIPTION	19
<b>2.2 MODELING OF MSF PLANTS.....</b>	<b>21</b>
2.2.1 SIMPLE MATHEMATICAL MODELS	21
2.2.2 DETAILED STEADY STATE MATHEMATICAL MODELS	22
2.2.3 MODEL STRUCTURE	24
2.2.4 MSF STAGE MODELING	25
<b>CHAPTER 3 MODELING AND SIMULATION.....</b>	<b>27</b>
<b>3.0 CHAPTER OBJECTIVES .....</b>	<b>27</b>
<b>3.1 METHOD OF CALCULATIONS .....</b>	<b>28</b>
3.1.1 INDEPENDENT PARAMETERS	28

3.1.2	SELECTED PARAMETERS	28
3.1.3	ASSUMPTIONS	30
<b>3.2</b>	<b>MATHEMATICAL MODEL</b>	<b>31</b>
3.2.1	PRIMARY CALCULATIONS	31
3.2.2	MAIN CALCULATIONS	34
3.2.3	PRIMARY DEPENDENT PARAMETERS	50
3.2.4	SECONDARY DEPENDENT PARAMETERS	50
3.2.5	OTHER DEPENDENT PARAMETERS	51
<b>3.3</b>	<b>PROGRAMS USED</b>	<b>52</b>

## **CHAPTER 4 RESULTS, DISCUSSION, AND PARAMETRIC STUDY..... 55**

<b>4.0</b>	<b>CHAPTER OBJECTIVES</b>	<b>55</b>
<b>4.1</b>	<b>RESULTS AT BASIC VALUES</b>	<b>57</b>
4.1.1	COMPARING MASS FLOW RATES	58
4.1.2	COMPARING THE OTHER 7 PARAMETERS	60
<b>4.2</b>	<b>PARAMETRIC STUDY FOR DESIGN NO.2</b>	<b>64</b>
4.2.1	RESULTS WHILE ( $T_{N+1}$ ) VARIES (FIXING EVERYTHING)	65
4.2.2	RESULTS WHILE ( $T_0$ ) VARIES (OPTIMIZING ( $T_{N+1}$ ))	71
4.2.3	RESULTS WHILE ( $T_N$ ) VARIES (OPTIMIZING ( $T_{N+1}$ ))	78
4.2.4	RESULTS WHILE ( $N$ ) VARIES	84
4.2.5	RESULTS WHILE ( $\Delta T_c$ ) VARIES	91
4.2.6	RESULTS WHILE ( $T_c$ ) VARIES	99
4.2.7	RESULTS WHEN ( $T_{SD}$ ) VARIES	106
4.2.8	RESULTS FOR DIFFERENT ( $Y_S$ )	114
<b>4.3</b>	<b>DISCUSSION</b>	<b>123</b>
4.3.1	COMPARING THE 2 DESIGNS	124
4.3.2	PARAMETRIC STUDY OF DESIGN #2	125

## **CHAPTER 5 CONCLUSIONS AND PLANT OPTIMIZATION..... 129**

<b>5.1</b>	<b>PLANT PERFORMANCE OPTIMIZATION</b>	<b>129</b>
5.1.1	OPTIMIZED RESULTS AT STANDARD ENVIRONMENTAL CONDITIONS	129
5.1.2	OPTIMIZED RESULTS AT SUMMER AND HIGH SALINITY	134
5.1.3	OPTIMIZED RESULTS AT WINTER AND HIGH SALINITY	139
5.1.4	OPTIMIZED RESULTS AT SUMMER AND LOW SALINITY	144
5.1.5	OPTIMIZED RESULTS AT WINTER AND LOW SALINITY	149
5.1.6	BEST POSSIBLE PLANT PERFORMANCE	154
<b>5.2</b>	<b>CONCLUSION</b>	<b>159</b>
<b>5.3</b>	<b>FUTURE WORK</b>	<b>160</b>

## **REFERENCES .....A**

## **APPENDIX 1: SAMPLE OF THE MATLAB CODE ..... E**

## **APPENDIX 2: RESULTS WHILE FIXING THE OPTIMIZATION PARAMETERS ..... P**

6.1.1	RESULTS WHILE ( $T_0$ ) VARIES (FIXING ( $T_{N+1}$ ))	P
6.1.2	RESULTS WHILE ( $T_N$ ) VARIES (FIXING ( $T_{N+1}$ ))	W
6.1.3	RESULTS WHILE ( $N$ ) VARIES (FIXING $T_{N+1}$ )	CC
6.1.4	RESULTS WHEN ( $TSO$ ) VARIES (FIXING $T_C$ )	II