

**ENHANCING THE THERMAL PERFORMANCE OF
THE GAS TURBINE UNIT IN KELANITISSA
COMBINED CYCLE POWER PLANT USING INLET
AIR EVAPORATIVE COOLERS**

R.S. Chathuranga

(199431C)

Degree of Master of Engineering

Department of Mechanical Engineering

University of Moratuwa

Sri Lanka

February 2024

**ENHANCING THE THERMAL PERFORMANCE OF
THE GAS TURBINE UNIT IN KELANITISSA
COMBINED CYCLE POWER PLANT USING INLET
AIR EVAPORATIVE COOLERS**

R.S. Chathuranga

(199431C)

Thesis/ Dissertation submitted in partial fulfilment of the requirements for the
degree of Master of Engineering in Mechanical Engineering

Department of Mechanical Engineering

University of Moratuwa

Sri Lanka

February 2024

DECLARATION

I declare that this is my own work and this thesis/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.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis/dissertation, in whole or in 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:

R.S.Chathuranga,
199431C

The above candidate has carried out research for the Masters/MPhil/PhD thesis/Dissertation under my supervision.

Name of the supervisor: Prof. J. G. A. S. Jayasekara,

Department of Mechanical Engineering,

University of Moratuwa,

Sri Lanka.

Signature of the supervisor:

Date:

ACKNOLEGEMENT

This study of research report was prepared as a part of my M. Eng. program offered by the University of Moratuwa, Sri Lanka. During the course of this study, there were many individuals who supported me in various ways to complete this work successfully. I take this opportunity to great many thanks that supported and helped me during writing this report.

First, I offer my sincere gratitude to my supervisor of this study Prof. J. G. A. S Jayasekara, senior lecturers of Department of Mechanical Engineering, University of Moratuwa for the support given to me with knowledge and guidance devoting his valuable time. Also, I offer my gratitude to staff of the Department of Mechanical Engineering, University of Moratuwa for the assistance given to me to complete this research.

I am thankful to operation and maintenance staff of Kelanitissa Combined Cycle Power Station, Ceylon Electricity Board and my specially thanks also go to the senior electrical Superintendents of the powerstation, Mr. Chula Sri Jagathmithra, Mr. D. D. R Jayasiri and Mr. Mahinda de Silva gave them great assistance, facilitation, information and data for achieving my research.

I would be also thankful to Mr. Nipun Tanthrigoda, assistant lecturer of the open university of Sri Lanka for giving me great assistance, information and motivation.

I also extend my heartfelt thanks to my family for this corporation and encouragement given me. Further, I should thank all the friends who gave their support path for completing the report. Finally, I thank to my family members including my wife, daughters, son, father and mother for supporting and encouraging me to complete this research study.

ABSTRACT

This project report presents a study on the potential benefits of using an evaporative cooling system to reduce the temperature of the air entering the gas turbine at the Kelanitissa Combined Cycle Power Plant in Sri Lanka. The study was motivated by the fact that the plant's capacity is reduced during periods of high ambient temperature due to the decrease in air density and mass flow rate to the gas turbine.

The study began with a literature survey on gas turbine inlet air cooling methods, advantages and disadvantages, theoretical background, and gas turbine operation. Next, field measurements and historical data were obtained to develop a relationship between ambient temperature and turbine performance. Energy calculations were then performed to determine the required level of inlet air temperature and to select a suitable evaporative cooler. Finally, a technical and economic feasibility study of the system was conducted.

The study found that an evaporative cooling system has the potential to significantly improve the thermal performance of the Kelanitissa Combined Cycle Power Plant. By reducing the temperature of the air entering the gas turbine, the system can increase power output, improve thermal efficiency, and reduce fuel consumption. Additionally, the system is cost-effective and has a relatively short payback period.

Based on the findings of the study, it is recommended that an evaporative cooling system be installed at the Kelanitissa Combined Cycle Power Plant. The system would provide significant benefits to the plant and the country as a whole, including increased power generation capacity, improved efficiency, reduced fuel consumption, and lower emissions.

TABLE OF CONTENTS

CHAPTER 01

INTRODUCTION.....	01
1.1 General Overview of Gas Turbine Power Plants.....	01
1.2 Background of the Kelanitissa Combined Cycle Power Plant.....	02
1.3 Problem Statement.....	04
1.4 Aim.....	05
1.5 Objectives.....	05

CHAPTER 02

METHODOLOGY.....	06
------------------	----

CHAPTER 03

LITERATURE REVIEW.....	07
3.1 Standard Environmental Condition of Gas Turbine Operations.....	07
3.2 Charge Air Cooling Related Studies.....	08
3.3 Types of Inlet Air Cooling Methods.....	09
3.3.1 The Fogging System.....	09
3.3.2 The Evaporative Cooling System.....	11
3.3.3 The Mechanical Refrigeration (M/R) System.....	12
3.3.4 The M/R System Integrated With Ice Storage.....	13
3.3.5 The M/R System Integrated With Chilled Water Storage.....	13
3.3.6 The Vapour Absorption Cooling System.....	14

CHAPTER 04

THEORETICAL ANALYSIS OF THE GAS TURBINE.....	16
4.1 Theoretical Background of the Single Shaft Gas Turbine.	16

CHAPTER 05

DATA COLLECTION OF THE POWER PLANT.....	20
5.1 General Plant Descriptions of KCCP Gas Turbine Unit	20
5.2 Environmental Condition of the Power Station	21
5.3 Operation Condition of the Power Station	22
5.4 Collecting of Running and Historical Data of the Power Station	24
5.4.1 Machine Recorded Historical Data Collection.....	24
5.4.2 Manual Historical Data Collection.....	25
5.5 Conclusion of the Data Analysing.....	27

CHAPTER 06

NUMERICAL ANALYSIS.....	28
6.1 Numerical Analysis of the KCCP.....	28
6.1.1 Performing Mathematic Equations of the Brayton Cycle.....	29
6.1.2 Performing mathematical computations of the Psychometric Chart.....	33
6.2 Increment of P/O After Installation of Evaporative Cooler.....	37
6.3 Improvement of Thermal Efficiency Installation of Evaporative Cooler.....	39
6.4 Reduction of Fuel Consumption Installation of Evaporative Cooler.....	40

CHAPTER 07

EVAPORATIVE COOLER DESIGN.....	41
7.1 Theoretical Analysis of the Evaporative Cooler.....	41

7.2 Capacity of an Evaporative Cooler.....	41
7.3 Installation of the Evaporative Cooler.	42
7.4 Economic Analysis of the Proposed Evaporative Cooler.	42
7.4.1 Cost of saving due to extra power generation.....	43
7.4.2 Cost of equipment and installation of evaporative cooler.....	43
7.4.3 Cost of operation of the evaporative cooler per year.....	44
7.4.4 Cost of maintenance for the evaporative cooler per year.....	45
7.4.5 Payback Period.....	46

CHAPTER 08

CONCLUSION.....	47
REFERANCES.....	49
APPENDICES.....	50

LIST OF FIGURES

Figure No.	Description	Page No.
1.1	Simple cycle gas turbine layout.....	02
1.2	Kelanitissa combined cycle power plant.....	02
1.3	Layout of Combined cycle power plant	03
3.2	Design characteristics with inlet air temp of gas turbine.....	07
3.3	Schematic diagram of fogging system.....	10
3.4	Fogging nozzle.....	10
3.5	Schematic diagram of evaporative cooling system.....	11
3.6	Evaporative cooling system.....	11
3.7	Schematic diagram of direct type M/R system.....	12
3.8	Schematic diagram of indirect type M/R system.....	12
3.9	Schematic diagram of M/R with ice storage.....	13
3.10	Schematic dia. of M/R system with chilled water storage.....	13
3.11	Schematic diagram of vapour absorption cooling system.....	14
3.12	Li-Br absorption chiller system.....	15
4.1	3D view of single shaft gas turbine unit.....	16
4.2	Schematic diagram of a single shaft gas turbine.....	17
4.3	PV and TS diagram of the Brayton cycle.....	17
5.1	Design data of Kelanitissa combined cycle power plant.....	21
5.2	Average min and max temperature distribution in Colombo district.	22
5.3	Average relative humidity distribution in Colombo district.....	22
5.4	Gas turbine runs with different inlet air temperature conditions.....	23
5.5	Influence of daily power output vs air temperatures.....	24
5.6	Influence of monthly power output vs air temperatures.....	25

5.7	Thermo meters of wet bulb, dry bulb and RH indicator.....	25
6.1	Online data collection while running base load mode of the plant...	28
6.2	Psy. Chart while running under the active power of 99.4 MW	34
6.3	Psy. Chart while running under the active power of 106.2 MW	35
7.1	Evaporative cooler 3D model.....	40
7.2	Installation of the eva. cooler in side of the air filter house.....	41

LIST OF TABLES

Table No.	Description	Page No.
5.1	Running data of the turbine generator.....	23
5.2	Running Data of the turbine generator.....	26
6.1	Different types of GE gas turbine performance characteristics.....	29
6.2	Calculated net efficiencies of the gas turbine	32
6.3	Data collection running turbine with different load and tem.....	33
6.4	Ambient temperature vs fuel consumption and active power.....	36

LIST OF CHARTS

Chart No.	Description	Page No.
5.1	R/H, Ambient temperature & Active power Vs Time Graph.	27
6.1	Net efficiency Vs Ambient temperature graph.	33

LIST OF ABBREVIATIONS

Abbreviation	Description
GT	Gas Turbine
ST	Steam Turbine
HRSG	Heat Recovery Steam Generator
NG	Natural Gas
HFO	Heavy Fuel Oil
KCCPS	Kelanitissa Combined Cycle Power Station
GE	General Electrical
RH	Relative humidity
WBT	Wet Bulb Temperature
DBT	Dry Bulb Temperature
CPD	Compressor Discharge Pressure
BTU	British Thermal Unit
MR	Mechanical Refrigeration
hr	Hour
cfm	Cubic Feet Per Minutes
Lkr	Sri Lankan Rupees
USD	United State Dollers