

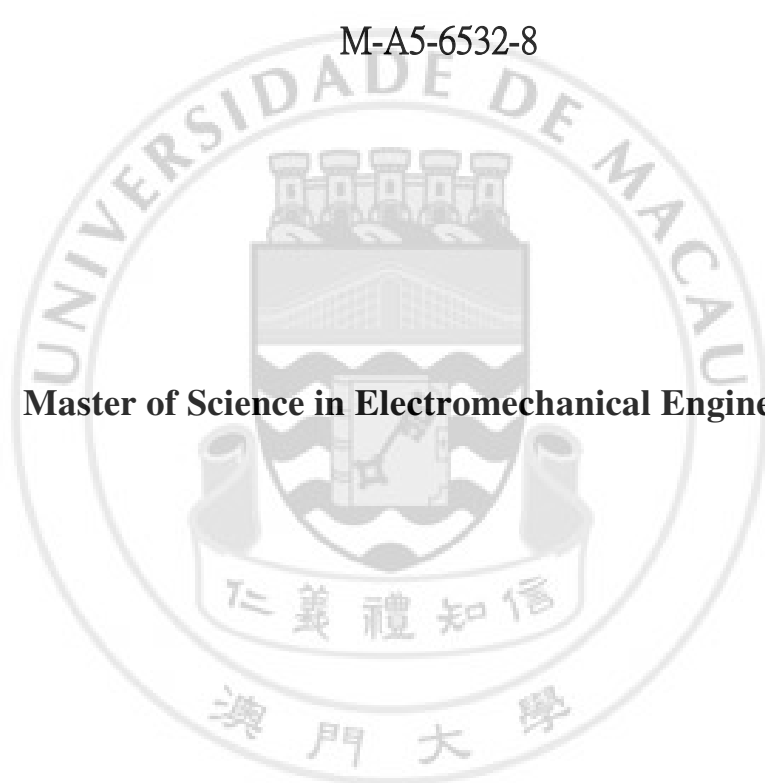
**Investigation on Energy Efficiency of Electrical
Power System in Macau Coloane Power Plant**

by

Chan Lai Cheong alias Eduardo Chan

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**Faculty of Science and Technology
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A thesis submitted in partial fulfillment of the
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Approved by

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Date

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Abstract

INVESTIGATION ON ENERGY EFFICIENCY OF
ELECTRICITY POWER SYSTEM IN MACAU COLOANE
POWER PLANT

by Chan Lai Cheong alias Eduardo Chan

Thesis Supervisor: Assistant Professor Yan Su
Electromechanical Engineering

The dynamical energy efficiencies of electrical power systems in Macau Coloane power plant had been investigated. Thermodynamic models for the efficiency of a simple cycle water injection gas turbine with rotor air cooling application and multi-shaft combined cycle power plant (CCPP) were developed and validated by comparing to the real data from the power plant in Macau, which is composed by two water injection gas turbines (WIGT) fueled by natural gas, two heat recovery boilers and one steam turbine. The result obtained from the present model has higher accuracy compared to previous models due to the application of dynamic values of the parameters such as injected water ratio. The optimal value for the ratio of injected water is obtained based on the present thermodynamic model and validated by the measured electrical efficiency. The present model is helpful in the operation of the water injection gas turbine power plant and the CCPP system. Besides, the present study also developed a new real time prediction models for output power and energy efficiency of solar photovoltaic (PV) systems. These models were validated using measured data of a grid-connected solar PV system in Macau. Both time frames based on yearly average and monthly averages are considered. It is shown that the prediction model for the yearly/monthly average of the minutely output power fits the measured data very well with high value of R^2 . The online prediction model for system efficiency is based on the ratio of the predicted output power to the predicted solar irradiance. This ratio model is shown to be able to fit the intermediate phase (9am to 4pm) very well but not accurate for the growth and decay phases where the system

efficiencies are near zero. It is shown that the maximum monthly average minutely efficiencies vary over a small range of 10.81% to 12.63% in different months with slightly higher efficiency in winter months.

Keywords: Combined Cycle Power Plant; Gas Turbine; Photovoltaic Systems



TABLE OF CONTENTS

List of FIGURES	viii
List of TABLES	x
NOMENCLATURE	xi
GREEK SYMBOL.....	xiii
SUBSCRIPTS	xiv
Chapter 1: INTRODUCTION.....	1
1.1 INTRODUCTION OF THE STUDIED POWER GENERATION SYSTEM.....	1
1.1.1 INTRODUCTION OF THE SIMPLE CYCLE GAS TURBINE.....	2
1.1.2 INTRODUCTION OF THE CCPP.....	3
1.1.3 INTRODUCTION OF SOLAR PV SYSTEM	5
Chapter 2: ANALYSIS ON SIMPLE CYCLE EFFICIENCY OF THE WATER INJECTION GAS TURBINE WITH ROTOR AIR COOLING.....	9
2.1 INFORMATION FROM THE GAS TURBINE IN MACAU	9
2.2 THERMODYNAMIC MODEL OF THE GAS TURBINE	10
2.2.1 COMPRESSION PROCESS (1 TO 2)	11
2.2.2 COMBUSTION PROCESS (2 TO 3).....	12
2.2.3 EXPANSION PROCESS (3 TO 4).....	13
2.3 RESULT	14
Chapter 3: A THERMODYNAMIC MODEL FOR EFFICIENCY OF A MULTI-SHAFT COMBINED CYCLE POWER PLANT	24
3.1 INFORMATION FROM THE CCPP IN MACAU.....	24
3.2 THERMODYNAMIC MODEL OF THE CCPP.....	26
3.2.1 GAS TURBINE PROCESS (1 TO 4).....	27
3.2.1.1 Compressor Process of the GTs (1 to 2)	27
3.2.1.2 Combustion Process of the GTs (2 to 3)	28
3.2.1.3 Expansion Process of the GTs (3 to 4).....	29
3.2.1.4 Gas Turbine Cycle Efficiency.....	30

3.2.2 HEAT RECOVERY BOILER (4a →4g, 8→10 and 9→11).....	30
3.2.3 STEAM TURBINE CYCLE (5 →6→7→(8→10 & 9→11)→5).....	32
3.2.4 THE EFFICIENCY OF THE CCPP SYSTEM (5 →6→7→(8→10 & 9→11)→5).....	34
3.3 RESULT	35
3.3.1 MODEL VALIDATION	35
3.3.2 EFFECTS OF WATER INJECTION RATIO ON THE ELECTRICAL EFFICIENCY	37
3.3.3 THE ENHANCEMENT OF THE ELECTRICAL EFFICIENCY DUE TO THE STEAM TURBINE CYCLE.....	38
Chapter 4: REAL-TIME PREDICTION MODELS FOR OUTPUT POWER AND EFFICIENCY OF GRID-CONNECTED SOLAR PHOTOVOLTAIC SYSTEMS.....	39
4.1 THE GRID-CONNECTED PV SYSTEM IN MACAU	39
4.2 THE PREDICTION MODEL FOR OUTPUT POWER	40
4.2.1 PREDICTION OF THE ANNUAL MEAN MINUTELY OUTPUT POWER.....	44
4.2.2 PREDICTION OF THE MONTHLY MEAN MINUTELY OUTPUT POWER.....	45
4.3 THE PREDICTION MODEL FOR SYSTEM EFFICIENCY	46
4.3.1 THE PREDICTION MODEL FOR SOLAR IRRADIANCE	47
4.3.2 PREDICTION OF YEARLY AND MONTHLY MEAN MINUTELY SYSTEM EFFICIENCY	51
Chapter 5: CONCLUSION	58
REFERENCE.....	60

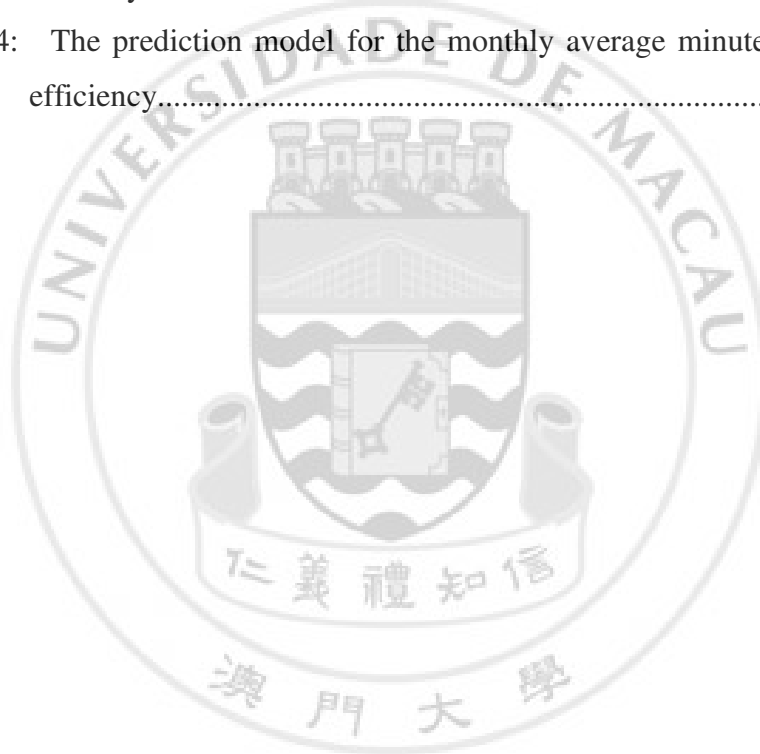
LIST OF FIGURES

<i>Number</i>	<i>Page</i>
Fig. 1.1: The schematic diagram of the major power generation systems in Macau Coloane Power Plant.....	1
Fig. 2.1: The schematic diagram for a gas turbine in Macau Coloane Power Plant	9
Fig. 2.2: T-S diagram for the gas turbine cycle	10
Fig. 2.3: Comparison of present model results with previous model of Rahman [70] and the measured data from gas turbine of the power plant in Macau.....	18
Fig. 2.4: The transient air and water ratio	19
Fig. 2.5: The relationship between the air ratio and the water ratio	20
Fig. 2.6: The transient simple cycle thermal efficiency and the ratio of water to fuel gas.....	21
Fig. 2.7: The relationship between the cycle thermal efficiency and the water ratio	22
Fig. 2.8: The measured data from the real water injection gas turbine with rotor cooling air for $\Delta\eta_{th}/\Delta r_w$ versus $1-r_p^{(1-\gamma_g)}/\gamma_g J(c_{p,w}T_w-LH_w)\eta/(Q_{in}/\dot{m}_f)$	23
Fig. 2.9: The relationship between the electrical efficiency and the water ratio	24
Fig. 3.1: The schematic diagram for CCPP in Macau Coloane Power Plant	25
Fig. 3.2: T-S diagram for the CCPP.....	27
Fig. 3.3: The schematic diagram for HRSG temperature profile.....	32
Fig. 3.4: Comparison of present model results with previous models and the measured data from Macau Coloane Power Plant	36
Fig. 3.5: The effects of the ratio of injected water on the gas turbine and steam turbine efficiency	37

Fig. 3.6:	The transient ratio of the model electrical efficiency for the gas turbines, steam turbine and CCPP, respectively	38
Fig. 3.7:	The transient ratio of the model energy ratio for the gas turbines, steam turbine over the CCPP	38
Fig. 4.1:	The daily profiles of output power generated from the PV system during the four days from March 4 to March 7, 2011	41
Fig. 4.2:	(a) Yearly and (b) monthly averages of the minutely output power	42
Fig. 4.3:	The daily profiles of solar irradiance measured during the four days from March 4 to March 7, 2011	47
Fig. 4.4:	(a) Yearly and (b) monthly averages of the minutely solar irradiance.....	50
Fig. 4.5:	Comparisons of predicted and measured yearly mean minutely system efficiency	54
Fig. 4.6:	Monthly average solar irradiance, ambient temperature, and wind speed	55
Fig. 4.7:	Comparison of predicted and measured monthly mean minutely system efficiency	57

LIST OF TABLES

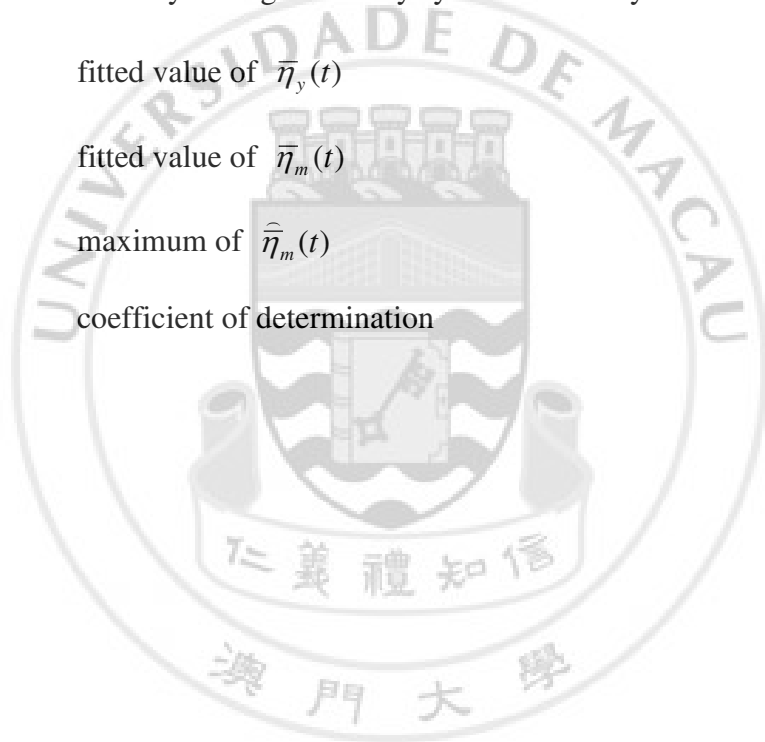
<i>Number</i>	<i>Page</i>
Table 4.1: PV module specifications	40
Table 4.2: Estimated Gaussian parameters based on the monthly average minutely output power	46
Table 4.3: Estimated Gaussian parameters based on the monthly average minutely solar irradiance.....	52
Table 4.4: The prediction model for the monthly average minutely system efficiency.....	56



NOMENCLATURE

A	estimate of peak parameter for the Gaussian model
C_p	specific heat at constant pressure, J/kg-K
C_v	specific heat at constant volume, J/kg-K
\dot{m}	mass flow rate, kg/s
LHV	lower heating value of fuel, J/m ³
LH _w	latent heat of water to steam, J/kg
p	pressure, N/m ²
P	output power, W
r	ratio based on mass flow rate over fuel
T	temperature, K
W	work, W
Q_{in}	input heat flux, J/m ³
t	time
d	day
N_y	number of days in a year
N_m	number of days in a month
$\bar{P}_y(t)$	yearly average minutely output power
$\bar{P}_m(t)$	monthly average minutely output power
$\hat{\bar{P}}_y(t)$	fitted value of $\bar{P}_y(t)$
$\hat{\bar{P}}_m(t)$	fitted value of $\bar{P}_m(t)$
R_{td}	solar irradiance at time t in day d

$\bar{R}_y(t)$	yearly average minutely solar irradiance
$\bar{R}_m(t)$	monthly average minutely solar irradiance
$\hat{\bar{R}}_y(t)$	fitted value of $\bar{R}_y(t)$
$\hat{\bar{R}}_m(t)$	fitted value of $\bar{R}_m(t)$
$\bar{\eta}_y(t)$	yearly average minutely system efficiency
$\bar{\eta}_m(t)$	monthly average minutely system efficiency
$\hat{\bar{\eta}}_y(t)$	fitted value of $\bar{\eta}_y(t)$
$\hat{\bar{\eta}}_m(t)$	fitted value of $\bar{\eta}_m(t)$
$\hat{\bar{\eta}}^*_m(t)$	maximum of $\hat{\bar{\eta}}_m(t)$
R^2	coefficient of determination



GREEK SYMBOL

η	efficiency
γ	specific heat ratio, C_p/C_v
μ	estimate of mean for the Gaussian model
ρ	density, kg/m^3
σ	estimate of standard deviation for the Gaussian model
ω	works per unit of mass, W/kg



SUBSCRIPTS

a	air
c	compressor
el	electrical energy
f	fuel gas
g	exhaust gas from combustion chamber
i	index number of shaft
j	index number of state point
m	mechanical energy
N	total number of the shafts
RAC	rotor cooling air
st	steam turbine
t	gas turbine
td	at time t in day d
th	thermal energy
w	water
1-11	state point number

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VITA OF AUTHOR

PUBLICATIONS

1. Su, Yan, Chan L.-C., Shu, L.J., and Tsui, K.-L., "Real-time Prediction Models for Output Power and Efficiency of Grid-Connected Solar Photovoltaic Systems," *Applied Energy*, 93, 319-326, 2012.
2. Su, Yan, and Chan L.-C., "Typical Day Prediction Model for Output Power and Energy Efficiency of a Grid-Connected Solar Photovoltaic System," *Proceedings of ICEE International Conference on Energy and Environment*, Tokyo, Japan, May, 2012.

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