Certificate

This is to certify that the thesis entitled, *Energy, Exergy, Exergoeconomic and Environmental (4E) analyses and Multi-objective Optimization of four Gas Turbine based Trigeneration systems*, submitted to the School of Engineering, Tezpur University in partial fulfilment for the award of the degree of Doctor of Philosophy in Mechanical Engineering is a record of research work carried out by *Joy Nondy* under my supervision and guidance.

All help received by him from various sources has been duly acknowledged. No part of this thesis has been submitted elsewhere for the award of any other degree.

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Joy Nondy

Dedicated To My Family.

For their endless love, support and encouragement

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Abbreviations

4E	Energy exergy exergoeconomic and environmental
ABS-I	Absorber of ACS-I
ABS-II	Absorber of ACS-II
AC	Air compressor
ACS	Absorption cooling system
ACS-I	Steam driven ACS
ACS-II	Gas driven ACS
APH	Air preheater
APTD	Approach point temperature difference
AWT	Ammonia water turbine
CC	Combustion chamber
CCPP	Combined cycle power plant
CHP	Combined heat and power
CON-I	Condenser of ACS-I
CON-II	Condenser of ACS-II
COND	Condenser of ORC layouts
COP	Coefficient of performance
CPC	Combined power and cooling
ECO	Economizer
ERS	Ejector refrigeration system
EV-I	Expansion valve of ACS-I
EV-II	Expansion valve of ACS-II

EVA-I	Evaporator of ACS-I
EVA-II	Evaporator of ACS-II
FH	Feed heater
FP	Feed pump
GA	Genetic algorithm
GDEA	Genetic diversity evolutionary algorithm
GEN-I	Generator of ACS-I
GEN-II	Generator of ACS-II
GT	Gas turbine
HRSG	Heat Recovery Steam Generator
HRVG	Heat recovery vapour generator
HVAC	Heating ventilation and air conditioning
IEA	International energy association
IHE	Internal heat exchanger
KC	Kalina cycle
MCDA	Multi-criteria decision analysis
MOEA	Multi-objective evolutionary algorithm
MOGA	Multi-objective genetic algorithm
MOPSO	Multi-objective particle swarm optimization
NIST	National Institute of Standards and Technology
NSGA-II	Non-dominated sorting genetic algorithm-II
OFWH	Open feed water heater
ORC	Organic Rankine cycle
OWH	Open water heater
PESA-II	Pareto envelope-based selection algorithm-II
PPTD	Pinch point temperature difference
PSO	Particle swarm optimization
R-ORC	Recuperative organic Rankine cycle
RR-ORC	Recuperative-Regenerative organic Rankine cycle

SHE-I	Solution heat exchanger of ACS-II
SHE-I	Solution heat exchanger of ACS-I
SOFC	Solid oxide fuel cell
SP-I	Solution pump of ACS-I
SP-II	Solution pump of ACS-II
SPEA-II	Strength Pareto evolutionary algorithm-II
SPECO	Specific exergy costing
ST	Steam turbine
SUP	Superheater
System-I	First configuration of CPC/CCHP system
System-II	Second configuration of CPC/CCHP system
System-III	Third configuration of CPC/CCHP system
System-IV	Fourth configuration of CPC/CCHP system
TOPSIS	Technique for order preference by similarity to ideal solution
VG	Vapor generator
VT	Vapor Turbine
WH	Water heater

Greek letters

Δ	Percentage change (%)
η	Energy efficiency (%)
ω	Effectiveness (%)
ϕ	Maintenance factor (–)
π	Dimensionless pressure (–)
θ	Dimensionless temperature (–)
ε	Exergy efficiency (%)

Nomenclature

$\bar{e}_k^{CH}$	Chemical exergy per mole of a component (kJ/kmol)
$\bar{M}$	Molecular weight (kmol)
ΔT_{pp}	Pinch point temperature difference (K)

$\dot{C}$	Cost rate (\$/h)
$\dot{C}_{D,k}$	Exergy destruction cost rate (\$/h)
$\dot{C}_{L,k}$	Exergy loss cost rate rate (\$/h)
$\dot{E}$	Exergy rate (kW)
$\dot{m}$	Mass flow rate (kg/s)
$\dot{n}$	Molar flow rate (kmol/s)
$\dot{Q}$	Heat Load (kW)
$\dot{W}$	Work rate (kW)
$\dot{Z}_k$	Capital cost rate (\$/h)
c	Cost per unit exergy (\$/GJ)
$c_{F,k}$	Cost per unit of fuel exergy (\$/GJ)
$c_{P,k}$	Cost per unit of product exergy (\$/GJ)
CRF	Capital recovery factor (–)
f_k	Exergoeconomic factor (%)
h	Specific enthalpy (kJ/kg)
j	Interest rate (%)
LHV	Lower heating value (kJ/kg)
N	Annual service hours (h)
n	Service life (years)
P	Pressure (kPa)
PEC_k	Purchase equipment cost (\$)
R	Universal gas constant (kJ/kmol.K)
r_k	Relative cost difference (%)
r_p	Air compressor pressure ratio (–)
s	Specific entropy (kJ/kgK)
S_{CO_2}	Specific CO_2 emission (kg/MWh)
T	Temperature (K)
T_{pz}	Adiabatic flame temperature (K)
w	Weights (–)

X	Mass percentage (%)
x_i	Mole fraction

Subscripts

0	Dead state
a	Air
ch	Chemical
D	Destruction
e	Exit
env	Environment
F	Fuel
g	Gas
gen	Generator
i	Inlet
kt	Kinetic
L	Loss
P	Product
ph	Physical
pt	Potential
r	Refrigerant
s	Steam/isentropic state
ss	Strong solution
tot	Total
ws	Weak solution