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

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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

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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
$\overline{P}_y(t)$	yearly average minutely output power
$\overline{P}_m(t)$	monthly average minutely output power
$\widehat{\overline{P}}_y(t)$	fitted value of $\overline{P}_y(t)$
$\widehat{\overline{P}}_m(t)$	fitted value of $\overline{P}_m(t)$
R_{td}	solar irradiance at time t in day d

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

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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

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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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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.

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