UNIVERSITI PUTRA MALAYSIA

MODELING OF METEOROLOGICAL DATA FOR COASTAL REGIONS OF OMAN

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BY

AHMED MOHAMMED AKAAK

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LIST OF SYMBOLS AND ABBREVIATIONS

ACF	Auto-Correlation Function
AR	Autoregressive process
ARMA	Autoregressive-Moving Average process
ARIMA	Auto-Regressive Integrated Moving Average
a_t	a probabilistic "shock" element
C	constant value
c	a scalar parameter in m/s.
CS	Coefficient of Skewness
E.P.F	Energy Pattern Factor
$E(v)$	the value of the empirical cumulative frequency distribution
D	relative humidity, %
$f(v)$	Weibull distribution Function
G_{sc}	solar constant, w/m^2
H	daily total radiation on a horizontal surface, MJ/m^2
H_0	the daily extraterrestrial solar radiation, MJ/m^2
$\frac{H}{H_0}$	the clearness index
iid	independent and identically distributed random noise
k	a dimensionless shape factor
K-S	the Kolmogorov-Smirnov test

MA	Moving Average process
N	the number of data points
n	the number of observations in time series
n	the day of the year (n= 1,2…365,or 366)
P	the air pressure (h Pa)
P_a	the available wind potential (W/m^2)
PACF	Partial Auto-Correlation Function
P_{aw}	the available power density using Weibull distribution parameters (W/m^2)
P_{max}	the maximum extractable power (W/m^2)
Q	maximum difference between empirical and theoretical cumulative distribution curves
$Q_{0.01}$	critical value of K-S test at 1% significant level
$Q_{0.05}$	critical value of K-S test at 5% significant level
Q_{LB}	the Ljung and Box test
Q_{ML}	the McLeod and Li test
R	the correlation coefficient
r(j)	the autocorrelation of residual time series at jth lag
r_k	estimated autocorrelation coefficient at lag k
$r_W(j)$	the sample autocorrelation of the squared data
S	the daily hours of sunshine, hrs
S_0	the maximum possible daily hours of sunshine, hrs

$\frac{S}{S_0}$	the relative duration of sunshine
T	the air temperature (K°)
Tp	the percentage of time (%)
T (v)	the theoretical cumulative frequency distribution function
Tx	maximum temperature, C^0
Tn	minimum temperature, C^0
ΔT	the daily temperature range, C^0
U	the number of pairs (i, j) for the Rank test
UBJ	Univariate Box-Jenkins
V	the number of values for the Difference-Sign Test
v	the measured wind speed in m/s
v_w	the estimated wind speed or the Weibull wind speed (m/s)
$v^3{}_w$	the mean cubed speed (m/s)
v_{wp}	the most probable wind speed using Weibull parameters (m/s)
W	the number of turning points for the Turning Point Test
x_t	the numerical value of an observation of the time series
x_{t-90}	differencing at lag 90
$y_1 \ldots y_n$	sequence of observations
Y_t	differencing at t lag t
ϕ	latitude with respect to the location of the surface in degrees
δ	declination angle in degrees

ω	sunset hour angle in degrees
Γ	the gamma function
ρ	the air density in (kg/m^3)
φ_{kk}	estimated partial autocorrelation coefficients at lag k
μ_U	the expected value of U
μ_V	the expected value of V
μ_W	the expected value of W
σ	Standard Deviation
σ^2	variance
σ_U	the variance of U
σ_V	the variance of V
σ_W	the variance of W
ϕ_1	fixed coefficient whose value determines the relationship between x_t and x_{t-1}
θ_1	ARMA coefficients

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Chairman: Prof. Hj. Mohd Yusof Sulaiman, Ph.D.

Faculty: Science and Environmental Studies

Information of solar radiation at any site is essential for the proper design and assessment of solar energy conversion systems. Empirical modeling is an important and economical tool for the estimation of solar radiation. The aim of this study is to find a suitable model to explain the solar radiation data in Oman.

Daily global solar radiation of Oman is modeled using measured climatological data of the four weather stations at different locations over the period of five years. These stations are: Seeb in the North, Sur in the East Coast, Masirah, an island off Central Oman and Salalah in the South. The data were obtained from the Directorate General of Civil Aviation and Meteorology in Oman. The daily extraterrestrial solar radiation, H_0, and the maximum daily hours of sunshine, S_0, are computed. The method used is based on Angstrom formula, which correlates relative global solar radiation to corresponding relative duration of bright sunshine. The daily temperature range (ΔT), the mean humidity (D) and the multiplication of all of them were added to the sunshine duration to give better results. Regression coefficients are obtained and used for prediction of global solar radiation. The results were satisfactory and can be used to predict weather data for stations where such data are not available.

Availability of wind energy and its characteristics for four weather stations in Oman has been studied based on primary data collected at these sites for a period of five years. The method used is based on the Weibull parameter distribution. The monthly average wind speed, the monthly mean scale and shape parameters and the monthly mean power density were determined for each station. The results showed that the mean wind speed, the scale and shape parameters and the mean power density have high values during summer season and low values during winter season. The K-S test was applied to the fitted model and showed excellent results for all the stations. As a result, wind data used are very well represented by the Weibull distribution function.

The Box-Jenkins method of time series analysis is applied to wind speed, relative humidity, and range in temperature for four locations in Oman over a period of five years. A non-stationary time series firstly is obtained. Then, a stationary time series has to be obtained by differencing technique to remove trends, cycles and seasonal components. The autocorrelation function (ACF) and the partial autocorrelation function (PACF) are obtained. The results showed that the data used can be fitted by AR and MA processes. After applying some diagnostic checking tests, the models obtained are capable of giving estimation within an acceptable mean percent error of 5%. Those models can be used to predict future values for the studied locations and areas closed by those stations.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

PEMODALAN DATA METEOROLOGI BAGI RANTAU PANTAI OMAN

Oleh

AHMED MOHAMMED AKAAK

Disember 1999

Pengerusi: **Prof. Hj. Mohd. Yusof Sulaiman, Ph. D.**

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Maklumat mengenai sinaran suria pada sebarang lokasi adalah penting untuk merekabentuk dan menilai sistem penukaran tenaga suria. Pemodelan empirikal adalah suatu kaedah yang penting dan ekonomi bagi menganggarkan sinaran suria. Tujuan kajian ini adalah untuk mencari kesesuaian beberapa model yang dapat menerangkan data sinaran suria Oman.

Sinaran suria global negara Oman dimodelkan menggunakan data kajicuaca yang diperolehi dari empat stesen cuaca yang berlainan untuk jangkamasa lima tahun. Stesen-stesen tersebut adalah : Seeb di Utara, Sur di Pantai Timur, Masirah, sebuah pulau berdekatan Oman Tengah dan Salalah di Selatan. Data diperolehi dari Directorate General of Civil Aviation and Meteorology Oman. Sinaran suria harian luar angkasa, H_0, dan tempoh maksimum harian penyinaran suria S_0 telah dikomput. Kaedah yang digunakan telah diasaskan kepada rumusan Angstrom yang mengkaitkan sinaran suria global relatif dengan tempuh penyinaran terik relatif yang sepadan. Untuk menghasilkan

keputusan yang lebih baik, julat suhu harian (ΔT), kelembapan min (D) dan pendaraban semua komponen tersebut dengan tempoh penyinaran juga diambil kira. Pekali regrasi diperolehi dan digunakan untuk meramal sinaran suria global. Hasil yang diperolehi adalah memuaskan dan boleh digunakan untuk meramalkan data cuaca bagi stesen lain yang tidak mempunyai data berkenaan.

Kewujudan tenaga angin dan ciri-cirinya telah dikaji menggunakan data asas bagi empat stesen kajicuaca Oman untuk jangkamasa lima tahun. Kaedah yang digunakan berasaskan kepada taburan parameter Weibull. Purata kelajuan angin bulanan, purata bulanan parameter skala dan bentuk, dan purata ketumpatan kuasa bulanan ditentukan bagi setiap stesen. Hasil menunjukkan bahawa purata kelajuan angin, parameter-parameter skala dan bentuk dan purata ketumpatan kuasa mempunyai nilai yang tinggi dalam musim panas dan bernilai rendah dalam musim sejuk. Ujian K-S telah dibuat ke atas model yang dipadankan dan memberikan keputusan yang baik untuk semua stesen. Oleh itu, data angin yang digunakan boleh diwakili oleh fungsi taburan Weibull.

Kaedah analisis siri masa Box-Jenkins telah digunakan kepada kelajuan angin, kelembapan relatif dan julat suhu untuk empat lokasi di Oman bagi jangkamasa lima tahun. Mula-mula, suatu siri masa yang tak-pegun telah diperolehi. Kemudian, suatu siri masa pegun perlu diperolehi dengan teknik pembezaan untuk melenyapkan komponen-komponen tetap, kitaran dan bermusim. Fungsi autokorolasi (ACF) dan fungsi autokorolasi separa (PAFC) telah diperolehi. Hasil menunjukkan bahawa data yang digunakan boleh dipadankan dengan proses AR dan MA. Setelah menyemak dengan mengenakan ujian diagnosis, model yang diperolehi berkemampuan memberi anggaran dalam lingkungan min peratusan yang boleh diterima sebanyak 5%. Model-model tersebut boleh digunakan untuk meramal nilai-nilai akan datang bagi lokasi-lokasi kajian dan kawasan-kawawan yang berhampiran dengan lokasi-lokasi tersebut.

CHAPTER I

INTRODUCTION

Knowledge on the availability of solar radiation at any site is essential in the design and the study of solar energy applications. Solar and wind energies are natural sources of energy that are clean, renewable and freely available for domestic use.

Global radiation (the sum of direct and diffuse radiation) is one of the most important input parameters to model solar system projects. The monthly mean daily global radiation on a horizontal surface is very useful for the analysis of solar process applications such as desalination, water pumping for irrigation, designing water heating systems, street lights, development of solar technologies for drying and solar assisted refrigeration, etc.

Wind energy is renewable and environmentally benign. Therefore, harnessing renewable wind energy at a certain site would help in the development of a region. The parameters for annual wind speed distribution are very important in determining the overall wind energy potential for a site. The monthly parameters are useful in estimating the size of a wind energy conversion system for applications such as powering, water pumping and windmills.

Geographical Location and Solar Radiation Data for Oman

Oman (21^0 $00^'$ N, 57^0 $00^'$ E) is located in the south east of Arabian Peninsula. Oman with 300,000 square kilometers of vary varied, striking terrain, occupies the south-eastern of the Peninsula, with a coastline which extending for 1,700 kilometers.

Dominated by an interior of jagged mountains simply called al-Hajr, 'the Rock', the country is a magic tapestry of different terrains. The mountains whose king at a soaring 3,075 meters is the terraced Jabal al-Akhdar (The Green Mountain), rise straight out of the coastal plains or the seam or soar out of the gravel plateaux and shifting dunes in the Interior.

The country ranges from the fjord-like barren majesty of the Musandam Peninsula that plunges into the Strait of Hormuz in the north, to the fertile Batinah plain that inclines south-east towards Muscat, from the vast, sandy edge of the Rub al-Khali (The Empty Quarter) through the mountains to the lush, monsoon-based near tropical Salalah plain in the south.

To the west Oman borders Saudi Arabia and the United Arab Emirates; to the south the Republic of Yemen, to the north the Strait of Hormuz, and to the east the Arabian Sea.

The climate varies from region to region. The coastal areas experience hot and humid climate, whereas the interiors have hot and dry climate with the exception of some higher locations where it is temperate all year round. In the southern region, the