UNIVERSITI PUTRA MALAYSIA

MODELING OF METEOROLOGICAL PARAMETERS FOR LIBYA

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By

MOHAMMED ALI SH-ELDIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of Requirements for the Degree of Master of Science

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DEDICATION

To the Truly Incorruptible among Men, whose

Nobility Restores our Gratitude and Reverence

For Human Life

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

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

Faculty: Science and Environmental Studies

Libya is a developing country with large natural resources. The surface of Libya amounts to 1,775,500 km² and is the fourth biggest African country. The population of Libya amounts to approximately 5 million and is concentrated on the coastal strips though it is divided among cities, villages, and rural areas, while the desert has some green, sunny, and windy oasis where many tribes live there. Due to the random distribution of the villages and oasis among the vast Libyan area it will be very expensive to provide these remote areas with electric energy from the country's grid of electricity. This reason encourages us to consider renewable energy options such as solar, wind, as alternatives. For successful energy research and applications, weather parameters of Libya (wind speed, sunshine duration, humidity, temperature, rainfall, and global solar radiation) have to be modeled.

For solar energy applications, information on global solar radiation for specific sites that have no records of weather data is required. A model based on Angstrom formula using weather data such as sunshine, temperature and humidity of five stations in Libya is described. The criteria of choosing the best formula among all formulae were based on R^2 value (coefficient of determination), and the value of modeling efficiency (**EFF**). We can accept any of equations 2.12, 2.19, and 2.20 to predict global solar radiation especially the nonlinear equation 2.20.

The wind is a free, clean, and inexhaustible energy source. It has served humankind well for many centuries by propelling ships and driving wind turbines to grind grain and pump water. The calculation of the output of a wind machine requires knowledge of the distribution of the wind speed. Weibull distribution has been applied to fit the probability distribution nature of wind speed. The analysis of the wind characteristics and the machine potentiality on the sites showed that over the year, Shahat has the highest mean wind speed followed by Sabha, and Tripoli. Also Shahat has the highest mean power density followed by Sabha, and Tripoli, where the second two sites (Sirt, and Al Kufra), have marginal mean wind speeds. The two most potential, and recommended sites for wind power density are Shahat, and Sabha with annual power densities of 336.85 W/m^2, 189.54 W/m^2 respectively, while the annual wind power density for Tripoli airport is 127.65 W/m^2 which is also acceptable and the annual mean wind speed for all sites are 6.18 m/s for Sabha, 5.28 m/s for Tripoli, and 7.33 m/s for Shahat. For the other sites such as Sirt, and Al Kufra the water pumping may be the only one use of the wind energy.

Time series analysis of the weather parameters have been carried out. To apply autoregressive process, transformation technique has been applied to generate stationary time series. Seasonal and non-seasonal auto regressive models describe our data for all stations. Time plot of the residuals, histogram of the residuals, auto correlation and partial auto correlation of the residuals indicate excellent results. The statistical tests of the residuals of the time series indicate excellent results for all locations of our study.

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

MODEL PARAMETER METEOROLOGI NEGARA LIBYA

Oleh

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Libya adalah negara membangun yang kaya dengan sumber-sumber semulajadi. Keluasannya adalah 1,775,500 km persegi merupakan negara keempat terbesar di Afrika. Jumlah penduduknya hampir 5 juta yang tertumpu di pesisir pantai. Taburan penduduknya terbahagi kepada kawasan bandar, kampung dan luar bandar manakala di kawasan gurun yang terdapat oasis, beberapa suku penduduk mendiaminya.

Memandangkan taburan rawak kampung dan oasis yang cantik di negara Libya yang luas itu, adalah amat mahal untuk menyediakan kuasa elektrik melalui grid tenaga negara. Keadaan ini menggalakan negara mempertimbangkan pilihan tenaga baru seperti tenaga solar dan angin sebagai pilihan. Untuk menjamin kejayaan kajian dan penggunaannya, parameter cuaca di Libya (kelajuan angin, tempoh sinaran, kelembapan, suhu, hujan, dan sinaran solar global) perlu dimodelkan.

Untuk penggunaan tenaga solar, maklumat sinaran solar global di tapak tertentu diperlukan bagi tapak yang tidak mempunyai tapak rekod kajicuaca. Model yang berasas Formula Angstrom yang menggunakan data sinaran matahari, suhu dan kelembapan di lima stesen telah digunakan. Kriteria pemilihan formula yang terbaik daripada formula-formula tersedia adalah berdasarkan nilai R^2 (koefisien penentuan), dan nilai kecekapan model (EFF). Kita boleh menerima sebarang persamaan 2.12,

2.19, and 2.20 untuk meramalkan sinaran solar global terutamanya pada persamaan 2.20).

Sumber tenaga angin adalah percuma, bersih dan tidak mengeluarkan bahan sisaan. Ia telah menyumbangkan tenaga kepada manusia dengan baik di beberapa negara menggerakkan kipas kapal dan turbin angin untuk menghancurkan bijiran dan mengepam air. Pengiraan hasil keluaran mesin angin memerlukan pengtahuan taburan laju angin. Taburan Weibull telah digunakan untuk padanan dengan taburan kebarangkalian semulajadi laju angin. Analisis ciri-ciri angin dan keupayaan (potensi) mesin di lapangan bagi setahun menunjukkan Shahat mempunyai purata tertinggi kelajuan angin diikuti oleh Sabha dan Tripoli. Shahat juga menunjukkan ketumpatan purata kuasa tertinggi diikuti oleh sabha dan Tripoli. Dua tapak lagi (Sirt dan Al Kufra) mempunyai purata halaju angin yang kecil. Kami mencadangkan dua tapak yang paling berpotensi untuk ketumpatan kuasa angin iaitu Shahat dan Sabha dengan ketumpatan kuasa tahunan masing-masing 336.85 W / m^2, 189.54 W / m^2 dimana ketumpatan kuasa tahunan di Lapangan terbang Tripoli adalah 127.65 W / m^2 juga boleh diterima dan kelajuan angin purata tahunan untuk semua Bandar adalah 6.18 m / s di Sabha, 5.28 m / s di Tripoli dan 7.33 m / s di Shahat. Pada bandar-bandar lain seperti Sirt dan Al Kufra, hanya pengempaman air mungkin boleh menggunakan tenaga angin.

Analisis siri masa parameter cuaca telah dilakukan. Untuk menggunakan proses regresif auto, teknik transformasi (pembezaan) telah digunakan untuk menghasilkan siri masa pegun. Model regresif auto bermusim dan tak bermusim menerangkan data daripada semua stesen. Plot masa, histogram, korelasi auto dan korelasi partial auto baki (residual) menunjukkan keputusan yang baik. Ujian statistik baki siri masa juga menunjukkan keputusan-keputusan yang baik bagi semua lokasi-lokasi yang dikaji.

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Finally, may Allah reward my supervisor and other lecturers for their dedication and service to humankind.

I certify that an Examination Committee met on 3rd April 2003 to conduct the final examination of Mohammed Ali Sh-Eldin on his Master of Science thesis entitled "Modeling of Meteorological Parameters for Libya" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. The Committee Members for the candidate are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirements for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MOHAMMED ALI SH-ELDIN

Date: 25 /April /2003
2003/ 4 /25

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LIST OF SYMBOLS AND ABBREVIATIONS

ACF	Autocorrelation function
Al Kuf	Al Kufra station
AR (p)	Autoregressive P^{th} order process
a and b	Parameters of Angstrom equation (2.12)
a, b, c, d, e, f, g and j	Parameters of equations (2.19 and 2.20)
avg	Average
Benena	Benena station
c and k	Parameters of Weibull distribution function
CDF	Cumulative distribution Function
D	Maximum difference between empirical and theoretical cumulative distribution curves
$D_{0.01}$	Critical value of K-S test at 1 % significant level.
$D_{0.05}$	Critical value of K-S test at 5 % significant level.
E.P.F (K_E)	Energy Pattern Factor
EFF	Modeling efficiency (equation 2.21)
F (v)	Probability density function of the wind (equation 3.2)
G sc	Solar constant (1367 W/m²)
H	Relative humidity
H	daily global solar radiation
$\overline{H}$	Monthly mean daily global solar radiation
Ho	Daily extraterrestrial solar radiation
$\overline{Ho}$	Monthly mean daily extraterrestrial solar radiation
IID	Independent and identically distributed random noise

K-S test	Kolmogorov-Smirnov test
M (v)	Cumulative distribution function of the wind speed
M	Month
MSE	Mean square error
N	Number of data points
N	Day of the year (n=1,2, ….365 or 366)
obs	Observed values
PACF	Partial autocorrelation function
PDF	Probability density function
P	Power density
Q	Values of Ljung-Box statistics
Q*	Values of McLeod and Li statistics
R	Correlation coefficient
r_h	Autocorrelation coefficient at lag h
r*	Autocorrelation of the squared residuals (equation 4.7)
S	Daily actual sunshine duration
$\bar{S}$	Monthly mean daily actual sunshine duration
So	Daily maximum possible sunshine duration
$\bar{S}o$	Monthly mean daily maximum possible sunshine duration
Sabh	Sabha station
Shah	Shahat station
Sirt	Sirt Station
sim	Simulated value
t	index of time step
T	Range in temperature extremes

Trip	Tripoli station
Trip-Apor	Tripoli Air Port station
v	wind speed
var	variance
WN	white noise
X (t)	Observations of stationary time series
Y (t)	Original data of time series
Y	Year
Z (t)	Uncorrelated white noise process with mean zero and variance σ^2_z
χ^2 test	Chi-square test
δ	Solar declination
φ	Latitude of the locations
$\varphi_{h,h}$	Partial autocorrelation coefficient at lag h
$\varphi_1, \varphi_2, \ldots \varphi_3$	Parameters of autoregressive p^{th} order process
σ	Standard deviation
σ^2	Variance
ω	Sunset hour angle
Γ	Gamma function
ρ	Air Density

CHAPTER I

INTRODUCTION

During the past few decades the advanced technological nations of the world have been engaged in an energy and resources race that has brought many countries to the position of energy crises. Many developing countries have also been engaged in this race during the last two decades or so. It is now widely recognized that the fossil fuels and other conventional resources, presently used in generation of electrical energy, may not be either sufficient or suitable to keep pace with the ever increasing world demand for electrical energy. The prospects for meeting this demand and avoiding a crisis in supply would be improved if new and alternative energy sources could be developed. Fortunately many such sources exist. Undoubtedly many of these would be exploited more and more in future.

Solar energy is the most abundant and constant stream of energy. It is available directly (solar insulation) and indirectly (wind energy, ocean thermal energy, geothermal energy, tidal energy, wave energy etc. etc.).

Magneto hydrodynamic systems, solar electric power plants, photovoltaic cells, fuel cells, wind energy, geothermal energy, tidal-energy, ocean thermal energy are important non-conventional energy sources. In addition to these the utilization of algae, organic wastes, bio-gas, rice straw etc. as energy sources has also been suggested and even used to some extent. Lot of research work pertaining to generation of energy from controlled nuclear fusion is in progress at many places in the world. Many scientists call it the ultimate energy source of the future. However many others doubt the possibility of this energy source being available commercially even after 3 or 4 decades. Development of the new energy sources and methods so that they become commercially viable will require a substantial commitment of the advanced technologically rich nations in future, Gupta (2001).

Research, development and demonstration efforts in renewable energy entail frequent collections, analysis and transmission of information. Where information takes the form of numerical data, it is necessary to employ appropriate data analysis and representation techniques so as to ensure efficient information utilization. The main goal of meteorological research on utilization of solar energy is to be able to inform the projector, producer, and user of solar technical installations, how much of solar energy is to be expected on the receiving surface of a certain orientation during a certain period of time. Furthermore to use solar energy, information on air temperature, wind, sunshine duration, relative humidity, etc, is also required. Global solar radiation is essential in the design and study of solar energy conversion devices. There are also other uses for such information including agricultural studies and meteorological forecasting.

Most of wind data models may be categorized into two types: descriptive statistics and probabilistic distribution models. The first category are graphs or power tables such as (speed histograms, speed or power duration curves and speed time plots), whereas the second takes the form of concise analytic expressions such as Weibull distribution. Majority of wind surveys contains both representations. Such representations, while in themselves useful summaries of data values, consist of transformed information and do not contain the real time element; they are unable to express wind speed dynamics explicitly in the time domain, a factor essential to operational analysis of wind power systems. Furthermore, these representations, apart from lending themselves to visual assessments, may not be adequate if indices or parameters are called for in comparative studies of data sets form, for example two sites or two periods of time. In fact, the need for a more appropriate model form arises in common cases where a potential site is so located that wind data are unavailable or insufficient: in such situations, techniques of data interpolation and extrapolation in space, in addition to forecasting in time, are necessary.

Some applications of statistical techniques to the meteorological parameters of Libya and Jordan are described in this thesis and it is hoped that these techniques can be more widely adopted to complement existing procedures.

Description of Location and Climate of Libya

Libya, the fourth largest state in Africa, is located in North Africa and lies between latitudes 33°N and approximately 20°N and longitudes 9°E and 25°E. It possesses a Mediterranean coastline of approximately 1820 Km in length. It is bordered by Egypt to the east, Sudan to the south-east, Chad and Niger to the south with Algeria and Tunisia to the west and north-west respectively. Libya has an area of approximately 1,775,500 sq. km, 3 times the surface area of France, and a population of about 4,500,000 (1995), the capital city being Tarabulus (Tripoli).